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AGRICULTURE 5.0 AND ARTIFICIAL INTELLIGENCE

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Abstract: In 2050, the planet will need more food because the world population will be close to 10 billion people. Since 2015, agriculture has opened the door to the incorporation of technologies such as autonomous robots and artificial intelligence. Intelligent systems allow automatic learning through data obtained from sensors, drones, and internet of things. These systems use algorithms to predict the behavior of variables such as soil quality, humidity, diseases, or sales price behavior. In this way, agriculture can function as the first link in an integrated, efficient, intelligent production chain, with permanent interconnectivity and timely decisions thanks to machine information processing through artificial intelligence.
Keywords: Machine learning, Precision agriculture, Regenerative agriculture.

INTRODUCTION

The Food and Agriculture Organization of the United Nations (FAO)[1] has pointed out that in 2050 the planet will need more food because the world population will be close to 10 billion people. To meet this need, mankind has been forced to use what is within its reach, such as knowledge, tools and devices to take advantage of the various forms of agriculture known as: subsistence, intensive, organic, digital, precision and regenerative[2].

Agriculture 5.0 is a concept that refers to the integration of technologies with a focus on maximizing agricultural production without neglecting sustainability, the regeneration of soil and water bodies, as well as the welfare of farmers and consumers. This work analyzes briefly the concept of Agriculture 5.0, its origin, evolution, its necessary relationship with AI, and last-generation Technologies (Figure 1).

AGRICULTURE AND ITS EVOLUTION TOWARDS 5.0

Agriculture 1.0, also known as traditional agriculture, is a fundamental part of the Neolithic revolution[3]. This revolution, characterized by the construction of permanent settlements, livestock raising and agriculture, implied a profound change in the way of life of the human species a little more than 10,000 years ago. Hunting and gathering were transformed into agricultural activities through the domestication of animals and the genetic modification of plants through human selection. This stage is identified by sowing and harvesting with simple tools such as the plow, sickles, rakes, threshing machines, and pickaxes; aside from tools derived from wheel invention, such as mills, Archimedes' screw, and devices for pumping water known as the ancient crankshaft[4]. Farmers acquired a great deal of empirical knowledge of plants, their nutrients, soil, atmospheric phenomena and traditional agricultural practices. Families produced enough for themselves and exchanged products. This Era was characterized by subsistence agriculture.

A second revolution, the Industrial Revolution, involved major advances in the mechanization of agricultural production systems during the 18th and 19th centuries, known as *Agriculture 2.0*[5]. The invention of the steam engine, and later the diesel engine, led to the invention of tractors adapted to particular crops and soils. In the early 20th century, the use of diesel-powered machines such as tractors, combine harvesters, mowers, and the use of chemical fertilizers, allowed farmers to work faster and more efficiently, improving crop yields.

The Green Revolution, or *Agriculture 3.0* from 1940 to 1970, refers to the massive adoption of the use of high-yield seeds, inorganic fertilizers, and synthetic pesticides, as well as the mechanization of cultivation, irrigation, and harvesting methods. These advances drove increases in crop yields, particularly in wheat, rice, and corn[6]. Agriculture became an expanding industry in terms of productivity. At this point, it is necessary to mention Norman Bourlaug contribution, an agronomist, geneticist, plant pathologist, and Nobel Peace Prize winner in 1970. Bourlang contributed to the improvement of crop yields under water stress in several countries (Argentina, United States, India, Mexico, Pakistan, Dominican Republic, among others) and provided sufficient food access to various sectors of the population as never before in history[7]. Despite the significant benefits in this period, *Agriculture 3.0* had negative environmental and social impacts such as: soil erosion, nutrient depletion, deforestation, water stress, burning of fossil fuels, damage to the biota due to excessive use of toxic substances, and impoverishment of farmers who were subordinated to products market sales price[8].

The digital era, which began at the end of the 20th century, developed precision agriculture or *Agriculture 4.0*[9]. Digital technologies such as global positioning system (GPS)[10], geographic information systems (GIS)[11] ,information and communication technologies (ICT)[12], drones (unmanned aerial vehicles UAV)[13-15], sensors[16-18], internet of things (IoT)[19], big data[20, 21], and robots[22-25], have been used for the automatic control of machines, such as pumps, tractors, irrigation systems, and harvesters that can operate with minimal human intervention. These systems provide real-time monitoring of harvests, which has led to more precise and efficient agriculture that manages and optimizes resources such as water, fertilizers and pesticides, improving decision-making.

Since 2015, *Agriculture 5.0*[26, 27] represents the most recent shift towards a highly technified, interconnected and related to Industry 5.0 agriculture. It is based on the integration

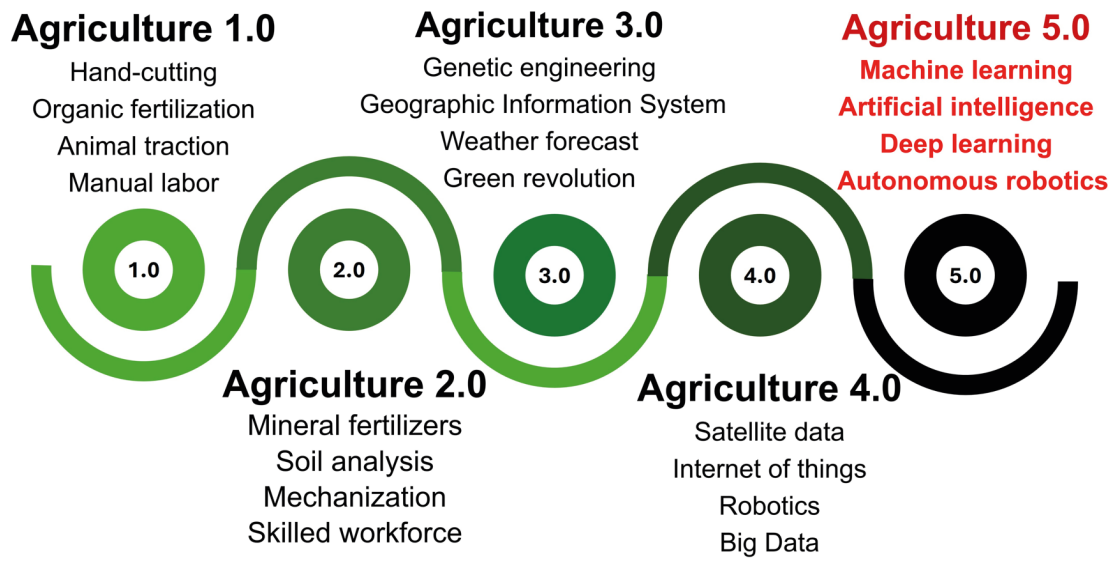

Figure 1. *Agriculture 5.0* evolution

Technologies	Biotechnology	Precision agriculture	Intelligent Systems Robotics	Massive data Predictive analytics Machine learning	Supply chain
Features	Improved species Modified species genetics Improves nutritional characteristics	Uses satellites, sensors, IoT, GPS and ICTs Follows up on crops, Measures properties of soil, water, crop Detects pests and diseases Intervenes in real time	Autonomous robots in: Sowing Harvest Irrigation Pest and disease control Nursery management	Predicts yields Optimizes resources and inputs such as water, energy, fertilizers, etc. Intervene and communicate on the variables under control.	Transparency Traceability Efficient agribusiness
Advantages	**Provides food safety**	**Reduces production costs**	**Farmer health and welfare**	**Reduces environmental impact**	**Reduces intermediaries**

Table 1. Technologies in *Agriculture 5.0* related to AI

of advanced technologies with AI such as predictive data analytics, smart sensors, autonomous robots[28], and machine learning[29] to improve agricultural supply chain management (Table 1). For example, crop monitoring and disease detection is performed using computer vision and machine learning algorithms known as Machine Learning. This technology makes it possible to identify early signs of diseases, nutritional deficiencies, or pests in crops, through aerial images captured by satellites or drones equipped with high-resolution cameras and advanced sensors, allowing quick, less costly interventions and treatments, preventing the spread of diseases and reducing the use of pesticides. Real-time data collection and analysis reduces post-harvest losses, improving inventory management and efficiency to custom delivery. Predicting market demand for agricultural products, improving logistics, optimizing transportation and product distribution (Figure 2).

With respect to biotechnology, AI has facilitated the research and development of genetically modified crops by analyzing large volumes of genetic data, helping to identify specific genes responsible for desirable traits such as disease resistance, rapid growth, tolerance to extreme weather conditions, and improved nutritional characteristics[30, 31].

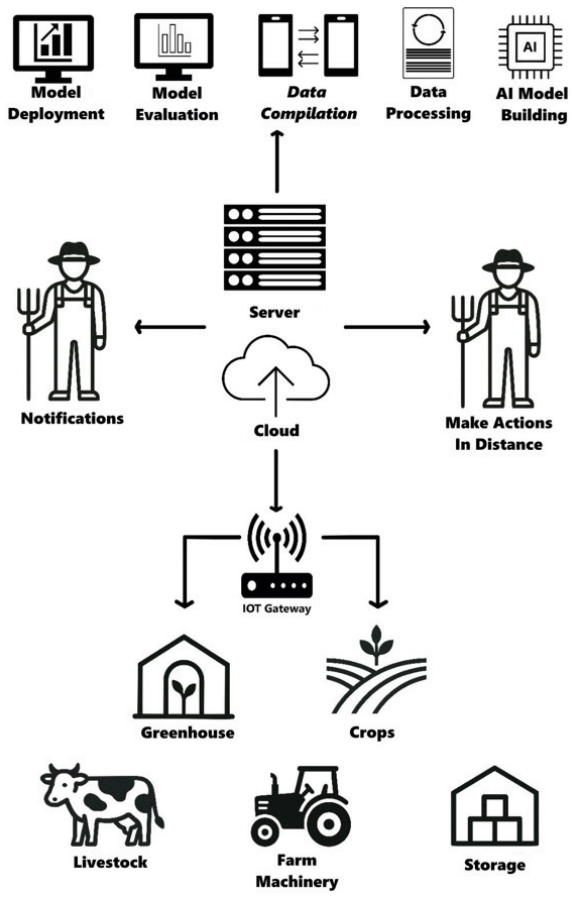

Figure 2. AI in *Agriculture 5.0*

But *Agriculture 5.0* goes beyond automation and digitization as it places a strong emphasis on the humanization, sustainability, and customization of agricultural production. This stage, known as regenerative agriculture[32], aims to ensure that both human well-being and the environment are respected. It also incorporates biotechnology to develop more resistant crops with better nutritional characteristics, as well as greater transparency in the supply chain[33]. This allows efficient and adaptable management to the specific needs of each farmer, taking into account factors such as soil type, climate and market preferences. In addition, regenerative agriculture plays an important role in this phase, promoting practices that not only to preserve the environment, but also restore it; such as crop rotation, the use of organic fertilizers, reforestation, reduction of the carbon footprint and greenhouse gas emissions, contributing to the efforts against climate change.

CONCLUSIONS

Artificial intelligence is already present in the daily activities of humanity, and the agricultural sector is no exception. For this reason, it is imperative to promote conversations and think over on robotics and digital agriculture, considering the related scope of intellectual property laws, the welfare of farmers and agricultural workers, social justice, educational policies, government spending and the value of public goods.

PERSPECTIVES

Agriculture 5.0 not only represents an advance in terms of technology, but also responds to the need for a more ethical and sustainable approach to production. In the future, it is expected to make greater use of renewable energies, drone management for monitoring, selective fumigation, and the development of autonomous systems for fully automated agriculture. The integration of AI in agriculture will make it possible to personalize the care of each plant, offering solutions to address global challenges such as climate change and the deterioration of natural resources. The panorama shows how agriculture is evolving towards a more technological, sustainable and ethical model, with a strong focus on science, technology, social and environmental responsibility.

REFERENCES

1. FAO (2018). The future of food and agriculture – Alternative pathways to 2050. Rome. 224 pp. https://www.fao.org/global--perspectives-studies/resources/detail/es/c/1169749/

2. OECD/FAO (2021). OECD-FAO Agricultural Outlook 2021-2030. OECD Publishing, Paris. https://doi.org/10.1787/19428846-en

3. Igamberdiev A. U. (2025). Human-driven evolution of cultivated plants and the origin of early civilizations: The concept of neolithic revolution in the works of Nikolai Vavilov. *BioSystems*, 247,105359. https://doi.org/10.1016/j.biosystems.2024.105359

4. Milliken, E. (2024). The neolithic revolution and women in early civilizations. Chapter 1 in *Women in world history: Pre--history to 1500 AD*. MHCC Library Press Open Educational Resources. https://mhcc.pressbooks.pub/womenworldhistory/chapter/chapter-1/

5. Clark G. (1999). Too much revolution: Agriculture in the industrial revolution, 1700–1860, Chapter 4 in Mokyr J. The british industrial revolution. An economic perspective 2nd Edition, 2018. New York. https://doi.org/10.4324/9780429494567

6. Headey D. D., and Hoddinott J. (2016). Agriculture, nutrition and the green revolution in Bangladesh. *Agricultural Systems*, 149, 122-131. https://doi.org/10.1016/j.agsy.2016.09.001

7. Borlaug N. (2007). Feeding a hungry world. *Science*, 318,359-359. https://doi.org/10.1126/science.1151062

8. Palmer Ch., Groom B., Sileci L., and Langton S. (2025). Biodiversity–food trade-offs when agricultural land is spared from production. *American Journal of Agricultural Economics*, 1-31. https://doi.org/10.1111/ajae.12530

9. Aggarwal S., and Verma A. (2022) Transformations in the ways of improving from Agriculture 1.0 to 4.0. *5th International Conference on Contemporary Computing and Informatics (IC3I)*, 170-174. https://doi.org/10.1109/IC3I56241.2022.10072298

10. Pandey P. Ch., Tripathi A. K., and Sharma J. K. (2021). An evaluation of GPS opportunity in market for precision agriculture. Chapter 16 in Petropoulos G. P., and Srivastava P. K. *GPS and GNSS Technology in Geosciences,* 337-349. Elsevier. https://doi.org/10.1016/B978-0-12-818617-6.00016-0

11. Yousefi, M. R., and Razdari, A. M. (2015). Application of GIS and GPS in precision agriculture (a review). International Journal of Advanced Biological and Biomedical Research, 3(1), 7-9. https://doi.org/10.3390/rs12193136

12. Pinto D. M., Oliveira P. de, Fachini Minitti A., Mansur Mendes A., Freitas Vilela G., Castro G. S. A., Nogueira Júnior L. R., Bogiani J. C., Rocha J. D., Lage Novaes R. M., Barros I. de, and Stachetti Rodrigues G. (2021). Impact assessment of information and communication technologies in agriculture: Application of the ambitec-TICs method. *Journal of technology management & innovation*, 16(2), 91-101. https://dx.doi.org/10.4067/S0718-27242021000200091

13. Puri V., Nayyar A., and Raja L. (2017). Agriculture drones: A modern breakthrough in precision agriculture. *Journal of Statistics and Management Systems*, 20(4), 507–518. https://doi.org/10.1080/09720510.2017.1395171

14. Van der Merwe D., Burchfield D. R., Witt T. D., Price K. P., and Sharda A. (2020). Chapter One, Drones in agriculture, in Sparks D. L., *Advances in Agronomy.* Academic Press,162, 1-30. https://doi.org/10.1016/bs.agron.2020.03.001

15. Rejeb A., Abdollahi A., Rejeb K., and Treiblmaier H. (2022). Drones in agriculture: A review and bibliometric análisis. *Computers and Electronics in Agriculture*,198,107017. https://doi.org/10.1016/j.compag.2022.107017

16. Sishodia, R.P., Ray, R.L., and Singh, S.K. (2020). Applications of Remote Sensing in Precision Agriculture: A Review. *Remote Sens,*12, 3136. https://doi.org/10.3390/rs12193136

17. Chugh B., Thakur S., Singh A. K., Joany R. M., Rajendra S., and Nguyen T. A. (2022). Electrochemical sensors for agricultural application. Chapter 7 in *Nanosensors for Smart Agriculture*, *Micro and Nano Technologies*. 147-164. https://doi.org/10.1016/B978-0-12-824554-5.00018-5

18. Liu X., Fan P., Su X., Cai L., Wu C., Qiu Y., Yu W., Xu F., Ping J., Wang P., Wan H., and Pan Y. (2024). MOFs/COFs-based hybrids for agricultural sensors: Current state of art and beyond. *TrAC Trends in Analytical Chemistry*,172,117603. https://doi.org/10.1016/j.trac.2024.117603

19. Khan Y., Su'ud M.B.M., Alam M.M., Ahmad S.F., Salim N.A., and Khan N. (2023). Architectural threats to security and privacy: A challenge for Internet of Things (IoT) applications. *Electronics*, 12, 88. https://doi.org/10.3390/electronics12010088

20. Majumdar J., Naraseeyappa S., and Ankalaki S. (2017). Analysis of agriculture data using data mining techniques: application of big data. Journal of Big Data, 4, 20. https://doi.org/10.1186/s40537-017-0077-4

21. Mustafa M.O., Elzein N.M., and SedAhmed Z.M. (2023). Analysis of data mining algorithms for predicting rainfall, crop and pesticide types on agricultural datasets. In Al-Emran M., Al-Sharafi M. A., and Shaalan, K. (eds*) International Conference on Information Systems and Intelligent Applications. ICISIA 2022.* Lecture Notes in Networks and Systems, vol 550. Springer, Cham. https://doi.org/10.1007/978-3-031-16865-9_58

22. Cheng C., Fu J., Su H., and Ren L. (2023). Recent advancements in agriculture robots: benefits and challenges. *Machines*, 11, 48. https://doi.org/10.3390/machines11010048

23. López-Gómez J. A., Patiño-Espejel J. E., Velázquez-López N., Sánchez-Cháve D. I., and Van Loon J. (2024). Design and comparison of two maize seeders coupled with an agricultural robot. *Machines*, 12, 935. https://doi.org/10.3390/machines12120935

24. Barbosa Júnior M. R., Santos R. G. d., Sales L. d. A., Oliveira L. P. d. (2024). Advancements in agricultural ground robots for specialty crops: An overview of innovations, challenges, and prospects. *Plants*, 13, 3372. https://doi.org/10.3390/plants13233372

25. Botta A., Cavallone P., Baglieri L., Colucci G., Tagliavini L., and Quaglia G. (2022). A review of robots, perception, and tasks in precision agriculture. *Applied Mechanics*, 3, 830-854. https://doi.org/10.3390/applmech3030049

26. Taha M. F., Mao H., Zhang Z., Elmasry G., Awad M. A., Abdalla A., Mousa S., Elwakeel A.E., and Elsherbiny O. (2025). Emerging technologies for precision crop management towards Agriculture 5.0: A comprehensive overview. *Agriculture*, 15, 582. https://doi.org/10.3390/agriculture15060582

27. De la Parte M. S. E., Martínez-Ortega J. F., Castillejo P., and Lucas-Martínez N. (2024). Spatio-temporal semantic data management systems for IoT in Agriculture 5.0: Challenges and future directions. *Internet of Things,* 25,101030. https://doi.org/10.1016/j.iot.2023.101030

28. Wu C., Tang X., and Xu X. (2023). System design, analysis, and control of an intelligent vehicle for transportation in greenhouse. *Agriculture*, 13, 1020. https://doi.org/10.3390/agriculture13051020

29. Godoy L. M. P., Salinas S. J., and Chaparro J. A. (2024). Machine Learning techniques used in the design of an automatic terrain identifier for a rover robot. In 2024 Institute of Electrical and Electronics Engineers ANDESCON, 1-6. https://doi.org/10.1109/ANDESCON61840.2024.10755543

30. Sakagianni A., Koufopoulou C., Koufopoulos P., Feretzakis G., Anastasiou A., Theodorakis N., and Myrianthefs P. (2025). Influence of microbiome interactions on antibiotic resistance development in the ICU environment: Insights and opportunities with Machine Learning. *Acta Microbiologica Hellenica*, 70(2), 14. https://doi.org/10.3390/amh70020014

31. Subeesh A., and Mehta C.R. (2021). Automation and digitization of agriculture using artificial intelligence and internet of things. *Artificial Intelligence in Agriculture*, 5, 278-291. https://doi.org/10.1016/j.aiia.2021.11.004

32. Jayasinghe S. L., Thomas D. T., Anderson J. P., Chen C., and Macdonald B. C. T. (2023). Global application of regenerative agriculture: A review of definitions and assessment approaches. *Sustainability*, 15, 15941. https://doi.org/10.3390/su152215941

33. Silva F. T. d., Baierle I. C., Correa R. G. d. F., Sellitto M. A., Peres F. A. P., Kipper L. M. (2023). Open innovation in agribusiness: barriers and challenges in the transition to Agriculture 4.0. *Sustainability*, 15, 8562. https://doi.org/10.3390/su15118562