MedCrave Online Journal of Biology and Medicine

Review Article

Open Access

Mitigating climate change impacts on agriculture through AI-driven crop improvement

Abstract

Artificial Intelligence (AI) and Machine Learning (ML) have introduced a favorable opportunity in the response to climate change. This review aims to highlight the use of artificial intelligence and machine learning for crop improvement under current climate change condition. These technologies have many opportunities and are very useful in the actualization of climate policies and decision without limitations on various parameters like improvement in spatial detail of climate models and the allocation of resources for crop improvement. These algorithms identify stipulations in extensive datasets and thus enhance foretelling of several climate parameters including frequency of extreme weather, rate of sea level rise and other climate issues. AI systems and ML systems also participate in environmental impact assessments such as the measurement of deforestation, loss of biodiversity, and carbon emissions. AI is essential to precision agriculture, optimizing resource allocation and boosting crop yields. AI and ML is very useful for the identification of climate smart genotypes, hence help in crop improvement. The prospects of AI and ML adoption into the climate science domain are bright. For global climate science objectives to be realized, AI and ML integration should be harnessed through different disciplines, appropriate data ecosystem and ethical standards.

Keywords: artificial intelligence (AI), machine learning (ML), crop improvement, datasets, environmental impact, crop yield

Volume 10 Issue 1 - 2025

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Received: January 20, 2025 | **Published:** February 26, 2025

Introduction

It is widely acknowledged that tackling climate change ought to be considered the most important challenge today. Climate change refers to the noticeable change in average weather patterns such as rainfall and warmth, averaged over long periods of time. In recent decades, however, it has been shown that active interference in the climate of the Earth's environment resulting in harmful global climate change can be halted due to people's aggressiveness. The increasing levels of CO_2 are predicted to result in crop fertilization, as the levels of energy needed in the warmer environment will be lower. While it could be said that climate change enhanced changes in the twentieth century affected countries in more of a positive light until 1980, these trends were further maintained by developed countries. This perspective then began to shift, such that latter developed nations began to bear these costs. In the 21st century, however, this is predicted to change so that developing as well as wealthy nations will sustain altercations by climate change.[1]

In the context of climate change agriculture is faced with the multifaceted problem of altered rainfall distribution, mean temperature, and extreme weather events, among others. Such factors as floods and droughts have a great deal of negative consequence on soil erosion. In addition, climate change modifies both the equilibrium of plant diseases and pests, as well as the amount of carbon dioxide and length of the growing seasons of crops. The other challenge is the rising sea levels. The temperature variation and the intensity of heat waves or cold snaps, the extremes of which crops and their yields are very sensitive to, are also a problem. The effect is determined by the stage of development of the plant in relation to the timing of the exposure to these extremes. Making matters worse, they aggravate the already difficult situation within cropping areas where water availability is limited, and rains are erratic, hence their irrigation strategies are unpleasant. Due to the increased uncertainty in rainfall amounts, farmers find it challenging to make productive decisions.[1]

Artificial Intelligence as we know it is revolutionizing many sectors, for instance we could mention the science of the improvement of cultivated plants. Artificial intelligence (AI) is widely recognized for its exceptional ability to examine and identify patterns within large datasets.[2] We explore the wide potential of AI technology in various aspects of plant breeding, including data collection, exploring new genetic materials preserved in seed storage, and plants producing try to identify the relationship between structure and phenotype to expedite the development of draught crops.[3] This approach will allow for the creation of crop varieties that are well-suited to the anticipated climatic conditions of the future.[1]

Additionally, these AI tools can enhance crop traits by enhancing the precision of gene editing technology to better predict the effect of specific genetic mutations on the associated plant traits. In addition, due to the advancement of AI assisted breeding methods, it will enhance the efficiency of precision breeding focusing on achieving localized optimizations for farming. They can plan better combinations for planting multiple crops in close proximity to one another or for alternating crops to make agriculture more sustainable and boost scientific yield in real-world greenery context.[4] Climate change effect the morpho-biochemical and molecular processes of economically important crop species. Therefore, the current review highlights the role of AI and ML for crop improvement under current climate change.

Methods

Data were collected through different databases: SciVerse Scopus, Scientific Electronic Library Online (SciELO), the Academic Search Tool (Scholar Google), etc. The search was developed using the subject descriptor, AI, ML, climate change, impact of climate change on agriculture, the role of AI and ML for crop improvement, etc.,

Selected studies

Role of AI (artificial intelligence) for crop improvement

AI employs multiple methodologies, such as machine learning, image recognition, and language processing, to drive agricultural productivity and efficiency.[5] Machine learning programs sort through huge sets of data to forecast weather, schedule irrigation for optimal results, and identify diseases in crops before they cause widespread damage. Image recognition systems can identify plant illness, infestation by pests, and nutritional deficiency through robotic monitoring systems.[6] **AI systems also use machine learning techniques to learn from patterns in the data to enhance their performance over time.**[7] Artificial intelligence (AI) is being used to rapidly create new plant types by combining large-scale genetic and trait analysis with modern breeding method (Figure 1).[6,9–11]

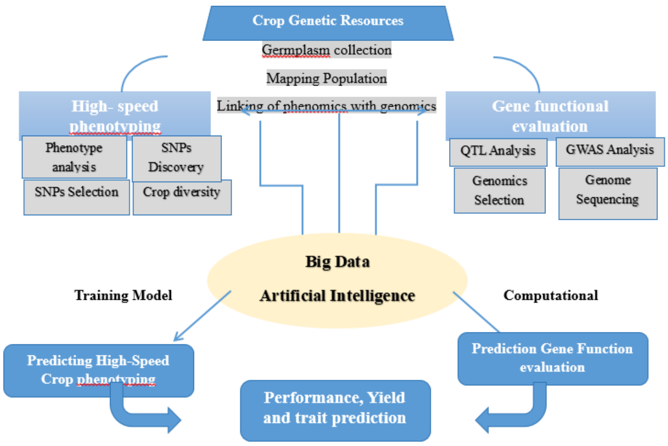

Figure 1 Applications of AI and ML for Crop improvement.[6,9–11]

Artificial intelligence (AI) in the domain of crop development is a major driving force and is being used to exploit high-throughput phenotyping and gene function analysis. Convenient and high-throughput methods were used to obtain very large amounts of phenotypic and genetic information from big farming and breeding populations. This huge dataset is the possibility for AI to be synthesized with several resources including crop phenotypic diversity, SNP Polymorphisms, QTL analysis, GWAS (whole genome sequencing), genome selection, and genome sequencing. AI systems are being used to predict crop phenotype through WGS while AI-fueled computations and model training make way for new breeding techniques.[12–15] Thus, AI integrated with phenomics and genomics techniques will likely bring about fast gene discovery related to agricultural phenotypes, thus accelerating crop development projects.[1]

AI-driven crop genomics and phenomics

Crop geneticists are setting out to find out more about the genetic information that is involved in plant phenotypes and to investigate the mechanisms known from molecular biology that lead to these characteristics, via the use of scientific data and bioinformatics. AI is a doorway to methodologies for solving complex biological issues such as metabolomics and proteomics, genomics, transcriptomics, and systems biology.[1] Improvements in technology have made it less complex and have increased the accuracy of identifying genetic differences and observable traits in plants, enabling the extraction of useful information from intricate datasets. Scientists, on the other hand, are on the verge of utilizing AI to analyze comprehensive chemical process datasets that will facilitate learning of molecular modifications in the course of non-living environmental strains.[6,18]

Scientists have employed AI and its generated models to manipulate the switch of records from basic DNA to bodily expressed trends, enabling them to research ability variations in herbal populations.[19] Specifically, AI can be useful resource breeders in reading genetic locations to enhance agricultural output through activating genetic algorithms and assisting huge-scale crop trait dimensions in both discipline and controlled settings,[19] further on, AI can be easily applied to biological information analyses and genome sequencing analyses to interpret several molecular structural components, including transcription factor binding sites.[20] Extensive RNA that isn't translated, small RNA-based regulators, genetic collaborations, genes encoding for proteins, selective RNA molecule sites,[21] and controlling DNA segments.[19,22]

Cutting-edge crop breeding programs collect these vast datasets and allow them to utilize all the diversity of genetic and trait information to identify new genes linked to specific characteristics. Luckily, artificial intelligence is the one that has pioneered a new era of data analysis and computation. Now, it is possible to simultaneously investigate massive datasets using it.[1] Furthermore, using AI to explore connections between potential genes and regulatory elements offers a new method to identify previously overlooked genes with potential for significant agricultural progress.[19,23] Artificial intelligence is becoming essential for collecting, examining, integrating, and overseeing genetic and trait information to enhance the ability of crops to withstand climate change (Table 1).[24]

Table 1 Successful Application of AI (Artificial Intelligence) in Plant Breeding

Sr. No.	Crops	Technologies used	Trait studied
1	Soybean	Best Linear Unbiased Prediction (BLUP) Neural Networks (NNs) Kemel Methods	Pre-harvesting and yield performance of plant[25]
2	Mustard Plant	Artificial Neural Networks (ANN)	Salt-Stress Tolerance and yield Performance of plant[26]
3	Ajwain	Artificial Neural Networks (ANN)	Oil content in plant and physical properties of Callus[27]
4	Corn	Neural networks (NN's) Deep Neural Networks (DNN's) Convolution Neural Networks (CNN's)	Salt-Stress Tolerance and yield Performance of plant[28–30]

Genome selection and predictive breeding

AI intelligence is further enhancing the accuracy and pace at which the development of crops is carried out which appeals for the use of a new data-driven agricultural approach, the writing of Algorithms for breeding crops. From this position we critically evaluate the impact of genomic prediction models mpsoyDNGP (multi-parent soybean deep neural genomic prediction) on the process of crop breeding. We discuss their potential, difficulties and their present-day application. It is recommended that feasible strategies to overcome presently existing challenges such as enhancing parent choice, accurately predicting the combined effects of multiple traits and genes, creating interpretable deep learning and considering environmental factors be employed. The researchers expect to further comprehend AI's capabilities in genetic prediction while seeking to broaden the understanding of AI in agriculture, in particular genomic predictions. We encourage additional research employing artificial intelligence in a manner that is sustainable and just to help tackle challenges of the food system.[31] However, a lot of time involved in the traditional process of breeding crops could be potentially cut down through the application of AI techniques. In a span of one season, AI models can be used to make predictions on aspects of the crop that prevents breeders from extending their work for multiple seasons. The breeding procedure will change significantly because AI will no longer be limited to making accurate predictions using vast genetic information.[32]

Evolution of genome prediction

The researchers expect to further comprehend AI's capabilities in genetic prediction while seeking to broaden the understanding of AI in agriculture, in particular genomic predictions. We encourage additional research employing artificial intelligence in a manner that is sustainable and just to help tackle challenges of the food system. Deep learning technologies have provided a significant breakthrough in genetic selection. For instance, DeepGS (Deep Learning Genomic Selection) offers more precise phenotypic value selection, which enhances conventional techniques like rrBLUP.[33] By integrating multi-omics data from plants and employing a deep neural network with a stacked structure of hierarchy for adaptive feature learning, DNNGP sets itself apart. This model is a useful tool to handle breeding data at many sizes, provides better prediction accuracy, and computes more quickly than conventional techniques.[34] The recently developed SoyDNGP (an advanced webserver designed to utilize the power of convolutional neural network-based models for the prediction of agronomic traits in soybean) model[21] is another example in which deep learning approaches are applied to genomics prediction in the context of crop breeding. Overall SoyDNGP is a major step forward in genome-wide variation data analysis.[31]

AI for predicting climate impact on crop yield

Agriculture is deeply intertwined with the environment. Conventional farming practices contribute to greenhouse gas emissions, deforestation, soil erosion, and water contamination. By adopting sustainable methods like conservation agriculture, agroforestry, and precision farming, we can mitigate agriculture's environmental impact and foster sustainable land and resource management. Climate change is marked by increased unpredictability. To bolster resilience against climate-related challenges, farmers must adapt. Strategies such as planting drought-resistant crops, optimizing irrigation, and employing climate-smart technologies can help mitigate losses and ensure continued production.[35] Climate-smart agriculture (CSA) is poised to revolutionize the sector through the integration of Artificial Intelligence (AI). This emerging paradigm positions AI as a key tool in addressing climate change challenges. This paper explores the interplay between AI and CSA research, focusing on AI's potential to enhance adaptation strategies in smart agricultural technologies. Agriculture is a major contributor to GHG (Greenhouse Gass) emissions, primarily methane from livestock and nitrous oxide from fertilizers and soil management. CSA aims to mitigate these emissions by promoting practices that reduce GHG release and enhance carbon sequestration in soils and vegetation. This includes precision nutrient management, agroforestry, conservation agriculture, and renewable energy use.[36–39]

AI-powered systems can analyze crop images to identify diseases, nutrient deficiencies, and pest infestations. By using computer vision and machine learning, AI detects visual patterns linked to crop health issues, enabling farmers to take early action and apply targeted treatments, reducing crop losses and optimizing resource use. AI is essential to precision agriculture, optimizing resource allocation and boosting crop yields. AI algorithms analyze data from sensors, drones, and satellites to provide insights into soil conditions, weather, and crop growth. This information allows farmers to tailor irrigation, fertilization, and pesticide applications to specific field areas, minimizing waste and maximizing productivity.[40]

Autonomous equipment precisely performs planting, harvesting, and weeding, enhancing efficiency and reducing manual labor. In livestock farming, robots automate feeding, monitoring, and milking, ensuring consistent and optimal care. AI aids in livestock health and welfare monitoring. Sensors and cameras collect data on animal behavior, feed intake, and health metrics. AI algorithms analyze this data, enabling early disease detection, prediction, and optimized feeding and breeding. This improves animal welfare, boosts productivity, and lowers veterinary expenses. AI aids in environmental monitoring, assessing soil health, water quality, and biodiversity. AI algorithms analyze sensor data to identify environmental risks and optimize resource use. This promotes sustainable farming, reduces environmental impact, and conserves natural resources.[40]

Enhancing drought tolerance through AI (artificial intelligence)

Using advanced technologies such as robotics, connected devices, neural networks, and machine learning, farmers are using safe solutions to more effectively deal with agricultural problems. This technology supports, imagery analysis, and remote monitoring of the weather for enhancing quality and increasing the number of harvests for farmers.[41,42]

Early identification and forecasting

Drought can be detected early by AI algorithms through the use of diverse sources such as weather conditions, satellite images depicting vegetation's health, and soil moisture data. AI brings hopes and enables both authorities and farmers to take proactive measures to lessen the detrimental effects of drought by issuing warnings and making accurate predictions. Afterwards, AI can also estimate how bad the drought will get and how long it will last, which allows for timely action. This ability in forecasting is very essential in the management of drought because it creates a time frame in which efforts to mitigate crop losses, conserve water, and offer assistance to the affected people can be made.[15,43]

Optimized water use

The artificial intelligence systems can enhance water management in agriculture by effectively assessing the soil moisture content and the crops' water needs. Meanwhile, with the help of data, the AI also helps the farmers to water their crops in an efficient manner reducing water wastage and ensuring that ideal conditions for the crops are maintained during the dry season.[44]

Just like virtual water managers for farmers, AI is able to evaluate information on soil moisture, climate, and the crop growth stage in order to determine how much water each crop needs. This allows farmers to plan their irrigation periods appropriately, making it possible to use the right quantity of water for each crop without having too much or too little water which affects crop yield or quality negatively.[45]

Development of drought resilient crops

One high-quality manner wherein synthetic intelligence boosts the speed of plant breeding is via analyzing genetic statistics to determine sure characteristics with drought tolerance inside crops. By predicting how different types of vegetation might perform all through varied drought-like situations, AI allows breeders to broaden crop types which have growth in water-pressured locations. This predictive capability has the power of AI enhance growing drought-resistant crops, therefore advancing agricultural resilience. In precis, artificial intelligence is hired to test giant sets of genetic facts for drought resistance genes. Once the ones genes are recognized, those can then be implemented for the duration of breeding programs to expand novel crop types. The change climatic scenarios which have been modelled are studied with the aid of breeders to recognize what could happen if the newly evolved type is cultivated with water scarcity conditions. These determined genes can later be utilized to create new crop varieties through breeding programs. Modeling one of a kind climate scenarios with the help of AI lets in breeders to expect how these new types will behave when there's a lack of water, for you to pick the maximum promising opportunities for cultivation in dry areas.[46–48]

Weed management using AI (artificial intelligence)

Weeds are continually reducing farmers' profits and crop yield. Yield reductions from uncontrolled weeds growth have been proven to be at levels that are as high as 50%. The production of dried beans and corn will be reduced by as much as 50% in case of weed uncontrolled growth. Wheat loses yield in a range between 48% and 60%. Soybeans experience a yield loss ranging between 8% and 55%. Sesame crops suffer more significant losses, which range from 50% to 75%. The degree of yield loss depends on the duration of exposure of crops to weeds and the distribution pattern of weeds.[35] Weeds are dangerous, as they exacerbate storm flooding and can thrive after fires. Some weeds are toxic and cause severe damage to the liver if ingested. Other weeds grow bigger than crops because they absorb all essential resources such as water, nutrients, and sunlight. Other weeds are toxic, leading to allergic reactions or threatening public health (Table 2).[35]

Table 2 Different AI techniques used in Weed Management.[35]

Sr. No.	Techniques	Uses	Limitations
1	Artificial Neural Networks (ANN), Genetic Algorithm.	High performance technique, it reduces trails and errors	Requires data in data in large amount
2	Mechanical control of pests using ROBOTICS, Sensor machine learning	It saves time and remove all the weed that causes resistance	Expensive, if we use machine constantly it will reduce the oil productivity
3	Support Vector Machine	It detects very quickly if there is any stress in plant.	It only detects low level of Nitrogen
4	Unnamed Aerial Vehicles (UAV)	High rate of weed can be detected within a short period of time	It is very expensive and it also requires vast human expertise

Challenges and limitation

Agriculture has faced severe challenges like inadequate irrigation, temperature fluctuations, depleting groundwater, food scarcity, and wastage. The future of farming largely relies on the implementation of different intelligent solutions. Although many researches are being conducted, and some applications are present, the sector still faces a lack of proper support. Agriculture is still in the nascent stage when the real-life problems of farmers are addressed and self-governing decision-making and predictive tools are being used. Applications should be more responsive to changing conditions, allow for instant decisions, and effectively utilize appropriate frameworks for gathering related information about unlocking the full potential of AI in agriculture.[49]

Another critical issue is that many agricultural AI tools are costly. This should be lowered so that the access becomes wider to farmers. By developing the open-source platform, it could be able to reduce costs and faster adoption among the farmers with more use of the tool. This technology may help boost crop yields while having a crop produced season after season. The performance of an intelligent system depends on the amount of data processed. Real-time AI systems constantly process large volumes of data, and attention to necessary or unexpected events must remain while the irrelevant information is filtered. Domain experts need deep knowledge about the purpose of the system to ensure that only important data is being used to optimize the effectiveness and accuracy of the system.[35]

Future directions and opportunities

Advances in Artificial Intelligence (AI) and Machine Learning (ML) offer unprecedented opportunities to understand, predict, and mitigate climate change. The future holds immense potential for integrating AI and ML into climate science. Continued progress in algorithms, computing power, and data availability will refine models, enhancing accuracy and precision. Advanced techniques like deep learning, reinforcement learning, and ensemble modeling will further propel climate modeling capabilities. The future of AI and ML in climate research hinges on interdisciplinary collaboration. Traditionally rooted in physical sciences, climate science now demands expertise in computer science, data science, and ethics. Collaborative efforts among climate scientists, computer scientists, statisticians, ethicists, and policymakers will advance AI and ML model development, application, and interpretation. This synergy fosters integration of diverse datasets, methodologies, and perspectives, leading to more comprehensive research. Cultivating a new generation of researchers adept in both environmental science and data science is crucial.[50]

While progress is substantial, challenges persist. Standardizing data formats, ensuring model interpretability, addressing ethical concerns, and integrating findings into policy remain priorities. Researchers must establish data collection and sharing protocols, enhance model transparency, uphold ethical guidelines, and facilitate policy integration. AI and ML are transforming climate change research beyond prediction. Enhanced models inform robust adaptation plans and optimize resource allocation for mitigation efforts. These technologies streamline decision-making, aligning actions with sustainability goals. From disaster response to land-use policies, AI and ML revolutionize climate change adaptation. AI can also foster citizen engagement through citizen science initiatives. By overcoming challenges and capitalizing on these technologies, we can build a sustainable and resilient future.[50]

Conclusion and recommendations

AI and ML are revolutionizing crop improvement by improving genomic prediction, precision breeding, and intelligent agriculture. Sophisticated models such as DeepGS and DNGP allow breeders to probe intricate genetic interactions, which enhance the selection of high-yield, stress-resistant, and disease-resistant crops. The technologies also maximize resource management, improving irrigation, fertilization, and pest management in precision agriculture. Yet, hurdles like data standardization, model interpretability, and ethics need to be overcome through inter-disciplinary collaboration between biotechnologists, agronomists, and AI experts. Next-generation developments in explainable AI, high-throughput phenotyping, and real-time monitoring of environmental conditions will further improve crop resilience, productivity, and sustainability, assuring long-term food security under a changing climate.

Acknowledgements

None.

Conflicts of interest

The authors declare that there are no conflicts of interest.

References

1. Khan MHU, Wang S, Wang J, et al. Applications of artificial intelligence in climate-resilient smart-crop breeding. *Int J Mol Sci.* 2022;23(19):11156.
2. MWAIS 2018 Proceedings. Midwest (MWAIS). Association for Information Systems.
3. Konar A. Artificial intelligence and soft computing: behavioral and cognitive modeling of the human brain. *CRC Press.* 2018.
4. Farooq MA, Gao S, Hassan MA, et al. Artificial intelligence in plant breeding. *Trends Genet.* 2024;40(10):891–908.
5. Jarrahi MH. Artificial intelligence and the future of work: Human-AI symbiosis in organizational decision making. *Business Horizons*. 2018;61(4):577–586.
6. Harfouche AL, Jacobson DA, Kainer D, et al. Accelerating climate-resilient plant breeding by applying next-generation artificial intelligence. *Trends in Biotechnology.* 2019;37(11):1217–1235.
7. Li Y, Zhou X, Li G. Bridging natural language and graphical user interfaces. In *Human-Comp. Int. Series*. 2021.pp. 463–493.
8. Dwivedi YK, Hughes L, Ismagilova E, et al. Artificial Intelligence (AI): Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. *International Journal of Information Management.* 2021;57:101994.
9. Esposito S, Carputo D, Cardi T, et al. Applications and trends of machine learning in genomics and phenomics for next-generation breeding. *Plants (Basel)*. 2019;9(1):34.
10. Reinoso-Peláez EL, Gianola D, González-Recio O. Genome-enabled prediction methods based on machine learning. *Methods Mol Biol.* 2022;2467:189–218.
11. Crossa J, Pérez-Rodríguez P, Cuevas J, et al. Genomic selection in plant breeding: Methods, models, and perspectives. *Trends Plant Sci.* 2017;22(11):961–975.
12. Mochida K, Koda S, Inoue K, et al. Computer vision-based phenotyping for improvement of plant productivity: a machine learning perspective. *GigaScience.* 2019;8(1):giy153.
13. Jung J, Maeda M, Chang A, et al. The potential of remote sensing and artificial intelligence as tools to improve the resilience of agriculture production systems. *Curr Opin Biotechnol.* 2021;70:15–22.
14. Caudai C, Galizia A, Geraci F, et al. AI applications in functional genomics. *Comput Struct Biotechnol J.* 2021;19:5762–5790.
15. Wang Z, Liu Y, Niu X. Application of artificial intelligence for improving early detection and prediction of therapeutic outcomes for gastric cancer in the era of precision oncology. *Semin Cancer Biol*. 2023;93:83–96.
16. Williamson HF, Brettschneider J, Caccamo M, et al. Data management challenges for artificial intelligence in plant and agricultural research. *F1000Research*. 2023;10:324.
17. Xu C, Jackson SA. Machine learning and complex biological data. *Genome Biol*. 2019;20(1):76.
18. Godwin ID, Rutkoski J, Varshney RK, et al. Technological perspectives for plant breeding. *Theor Appl Genet.*2019;132(3):555–557.
19. Mahood EH, Kruse LH, Moghe GD. Machine learning: a powerful tool for gene function prediction in plants. *Appl Plant Sci.* 2020;8(7):e11376.
20. Long P, Zhang L, Huang B, et al. Integrating genome sequence and structural data for statistical learning to predict transcription factor binding sites. *Nucleic Acids Res.* 2020;48(22):12604–12617.
21. Gao P, Zhao H, Luo Z, et al. SoyDNGP: a web-accessible deep learning framework for genomic prediction in soybean breeding. *Brief Bioinform.* 2023;24(6):bbad349.
22. Ernst J, Kellis M. Chromatin-state discovery and genome annotation with ChromHMM. *Nat Protoc*. 2017;12(12):2478–2492.
23. Tong H, Nikoloski Z. Machine learning approaches for crop improvement: leveraging phenotypic and genotypic big data. *J Plant Physiol.* 2021;257:153354.
24. Shen Y, Zhou G, Liang C, et al. Omics-based interdisciplinarity is accelerating plant breeding. *Curr Opin Plant Biol.* 2022;66:102167.
25. Uzal LC, Grinblat GL, Namías R, et al. Seed-per-pod estimation for plant breeding using deep learning. *Computers and Electronics in Agriculture.* 2018;150:196–204.
26. Niedbała G, Piekutowska M, Weres J, et al. Application of artificial neural networks for yield modeling of winter rapeseed based on combined quantitative and qualitative data. *Agronomy*. 2019;9(12):781.
27. Niazian M, Sadat-Noori SA, Abdipour M. Artificial neural network and multiple regression analysis models to predict essential oil content of ajowan (*Carum copticum L.*). *Journal of Applied Research on Medicinal and Aromatic Plants*. 2018;9:124–131.
28. Altuntaş Y, Cömert Z, Kocamaz AF. Identification of haploid and diploid maize seeds using convolutional neural networks and a transfer learning approach. *Computers and Electronics in Agriculture*. 2019;163:104874.
29. Montesinos-López OA, Martín-Vallejo J, Crossa J, et al. A benchmarking between deep learning, support vector machine and Bayesian threshold best linear unbiased prediction for predicting ordinal traits in plant breeding. *G3(Bethesda).* 2019;9(2):601–618.
30. Khaki S, Khalilzadeh Z, Wang L. Predicting yield performance of parents in plant breeding: A neural collaborative filtering approach. *PLoS One*. 2020;15(5):e0233382.
31. Feng W, Gao P, Wang X. AI Breeder: Genomic predictions for crop breeding. *New Crops*. 2024;1:100010.
32. Xu Y, Zhang X, Li H, et al. Smart breeding driven by big data, artificial intelligence, and integrated genomic-enviromic prediction. *Molecular Plant*. 2022;15(11):1664–1695.
33. Ma W, Qiu Z, Song J, et al. A deep convolutional neural network approach for predicting phenotypes from genotypes. *Planta*. 2018;248(5):1307–1318.
34. Wang K, Abid MA, Rasheed A, et al. DNNGP, a deep neural network-based method for genomic prediction using multi-omics data in plants. *Mol Plant*. 2023;16(1):279–293.

Citation: Farooq H, Mazhar R, Jan SA. Mitigating climate change impacts on agriculture through AI-driven crop improvement. *MOJ Biol Med.* 2025;10(1):29–34. DOI: 10.15406/mojbm.2025.10.00237

35. Eli-Chukwu NC. Applications of artificial intelligence in agriculture: A review. *Engineering, Technology and Applied Science Research.* 2019;9(4):4377–4383.

36. Yessengeldin B, Khussainova Z, Kurmanova A, et al. Exploitation of natural resources in Kazakhstan: judicial practice for foreign investment. *J East Asia Int Law*. 2019;12(1):169–179.

37. Ma X, Gryshova I, Khaustova V, et al. Assessment of the impact of scientific and technical activities on the economic growth of world countries. *Sustainability*. 2022;14(21):14350.

38. Wang J, Wang J, Zhang Y. Artificial intelligence in agriculture: applications, challenges, and perspectives. *J Integr Agric.* 2019;18(12):2774–2785.

39. Ramazanov S, Petrova M. Development management and forecasting in a green innovative economy based on the integral dynamics model in the conditions of "Industry - 4.0". *Ideas*. 2020;1(1):9–30.

40. Gryshova I, Balian A, Antonik I, et al. Artificial intelligence in climate smart agriculture: toward a sustainable farming future. *Access to Science, Business, Innovation in Digital Economy*. 2024;5(1):125–140.

41. Talaviya T, Shah D, Patel N, et al. Implementation of artificial intelligence in agriculture for optimisation of irrigation and application of pesticides and herbicides. *Artificial Intelligence in Agriculture*. 2020;4:58–73.

42. Ayed RB, Hanana M. Artificial intelligence to improve the food and agriculture sector. *Journal of Food Quality*. 2021:1–7.

43. Kwon J, Kim K, Jo Y, et al. Artificial intelligence assessment for early detection and prediction of renal impairment using electrocardiography. *Int Urol Nephrol*. 2022;54(10):2733–2744.

44. Xiang X, Li Q, Khan S, et al. Urban water resource management for sustainable environment planning using artificial intelligence techniques. *Environmental Impact Assessment Review.* 2021;86:106515.

45. Tariq R, Cetina-Quiñones A, Cardoso-Fernández V, et al. Artificial intelligence assisted technoeconomic optimization scenarios of hybrid energy systems for water management of an isolated community. *Sustainable Energy Technologies and Assessments*. 2021;48:101561.

46. Elsalahy HH, Bellingrath-Kimura SD, Roß C, et al. Crop resilience to drought with and without response diversity. *Frontiers in Plant Science*. 2020;11.

47. Ouahid S, Backhaus AE, Jimenez J, et al. Unveiling drought-resilient pathways: integrating high throughput phenotyping and multivariate modeling to enhance barley adaptation to climate change. 2023.

48. De Vries FT, Griffiths RI, Knight CG, et al. Harnessing rhizosphere microbiomes for drought-resilient crop production. *Science*. 2020;368(6488):270–274.

49. Javaid M, Haleem A, Khan IH, et al. Understanding the potential applications of artificial intelligence in agriculture sector. *Advanced Agrochem*. 2023;2(1):15–30.

50. Hamdan A, Ibekwe KI, Etukudoh EA, et al. AI and machine learning in climate change research: a review of predictive models and environmental impact. *World Journal of Advanced Research and Reviews*. 2024;21(1):1999–2008.