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AI Integrated Biotechnology versus Climate Resilient Agriculture, Healthcare and Food System: An Overview

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ABSTRACT
Artificial intelligence (AI) may be a game-changer for farmers coping with the escalating problems of climate change. AI models can predict and mitigate the wide-ranging impacts of climate change on agriculture, providing farmers with state-of-the-art tools to aid in their decision-making. As environmental issues intensify, AI integration is starting to move the game for climate-resilient agriculture. The advantages of AI and climate research working together in concert to recognize climate-related risks, namely, extreme weather, altered precipitation patterns, and new pest concerns. A thorough analysis is conducted of the possible advantages and challenges of widespread AI application in various agricultural situations. AI-powered technologies that combine computer vision, deep learning, reinforcement learning, and predictive analytics provide precise climate forecasting, early disease detection, and economical resource utilization. Machine learning techniques such as support vector machines, recurrent neural networks, and convolutional neural networks enhance crop monitoring, yield prediction, and soil quality assessment. Besides, reinforcement learning and Internet of Things integration enable smart irrigation systems and adaptive decision-making in unexpected climate conditions. This overview provides a comprehensive assessment of the use of AI and ML in precision agriculture, climate-smart farming, and sustainable land management. Edge AI, blockchain-based agricultural intelligence, and federated learning are some of the emerging concepts highlighted as possibly advantageous for future climate-resilient farming systems directly and/or indirectly impacting on health care and food system.
***Key words**: Agriculture, artificial intelligence, climate resilient, food system, healthcare.*

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I. Introduction

In biotechnology, artificial intelligence (AI) is already widely employed to address a range of issues. Among many others, these include pharmacology [1], proteomics [3], [4], metabolomics [5], pharmacogenetics [2], pharmacogenetics [10], functional and structural genomics [8,9], pharmacogenetics [10], and many more [11-13]. The capacity of biotechnology researchers to efficiently integrate cutting-edge AI solutions will be crucial to future advancements in this area. Currently, data storage, filtering, analysis, and sharing are critical components of the biotechnology sector. Big databases are already maintained by biotechnology corporations and other healthcare institutions worldwide. Enzyme research, chemical analysis of different chemicals, drug manufacturing, RNA and DNA sequencing, and other related biological processes all need robust AI software solutions to operate more quickly and reduce human labor errors. It is crucial to stress right away that all of the effective AI that we are discussing today depends solely on digital technology to operate. Thus, the initial step in any AI application is digitization. To facilitate task automation and data gathering and analysis, artificial intelligence (AI) systems are frequently combined with other digital technologies, including sensors, actors (also known as cyber-physical systems, or CPS), and technology.

In general, digital technology—which is based on digital computers—is essential to the creation and application of AI. Using digital technologies to radically alter how businesses, organizations, research institutes, and academic institution's function is known as "digital transformation."

Digital transformation in the biotechnology sector might include using new procedures and technologies to boost R&D speed, accuracy, and efficiency as well as facilitate the creation of completely novel and ground-breaking goods and services.

Digital transformation can hasten the creation and application of biotechnology By facilitating access to large data and automating some processes, artificial intelligence (AI) in biotechnology can enhance the effectiveness and precision of research and development.

1. What is AI?

The creation of "intelligent" robots has long been the focus of artificial intelligence (AI) in computer science [14], although the term intelligence is ill-defined, and even quantifying "intelligence" is very challenging [15].

Any component of intelligence, including learning, can theoretically be characterized with such precision that a machine might mimic it. The goal is to figure out how to teach robots to speak, create abstractions and concepts, solve a variety of issues that are currently only handled by people, and develop themselves [16]. Deep learning (DL), machine learning (ML), and artificial intelligence (AI) are all connected yet different. The following are some significant distinctions between these fields:

- Artificial Intelligence (AI) is a broad field and umbrella term that describes the development of intelligent systems that are capable of learning, solving problems, and making decisions—tasks that often require human intelligence.
- Machine learning (ML) is a branch of artificial intelligence that uses data patterns and insights to teach digital machines to carry out tasks without direct instructions.
- DL is a branch of ML that learns and makes choices using multi-layer artificial neural networks. It is especially helpful for tasks involving the analysis of enormous volumes of data, such text (e.g., ChatGPT) or photos (e.g., DALL-E2).

AI that represents knowledge symbolically (for instance, a dog is an animal with fur and four legs) and uses logical principles to manipulate those symbols in order to solve issues is known as symbolic AI. It is not the same as machine learning or deep learning, which identify patterns in data instead of depending on explicit rules. Since machine learning and deep learning have gained popularity for applications like image and speech recognition, symbolic AI is being utilized less frequently these days. [17-18]. Since its origin, artificial intelligence (AI) has been a very wide field, including everything from philosophical concerns to practical real-world applications [19]. Since AI was first established as a field of study six decades ago, it has had more ups and downs than any other subject. The first hype ended in the 1980s with a brutally cold AI winter, after expectations that were far too high—"gh" - "within 10 years, anything humans can do, a machine will be able to do" [20]. During this period, many scientists and the disillusioned industry moved away from artificial intelligence (AI); for a moment, the phrase itself was even on the verge of being outlawed.

II. AI IN BIOTECHNOLOGY

Although defining artificial intelligence (AI) can be difficult and different writers use different terms, such as "machine intelligence" [21], "computational intelligence" [22], and "artificial neural networks" [23], the term is widely recognized nowadays. Scientists at Dartmouth College in the United States of America coined the term artificial intelligence (AI) in 1955 when they said: "... every aspect of learning or any other One aspect of intelligence can be so accurately characterized that it can be replicated by a machine. “We’ll try to figure out how to teach computers to talk." create abstractions and concepts, solve issues that are now only handled by people, and develop themselves” [24]. AI has advanced quickly after years of development. from 2000 AI has been outperforming humans in tests such as picture, audio, and handwriting recognition, as well as language and reading comprehension [25].

2.1 AI in Agriculture Biotechnology

Despite minimal financial progress, the world's population is expected to approach 10 billion people by 2050, which would lead to a 50% increase in agricultural production over 2013 [26]. An important part of the country's economy and job creation is agriculture. It makes a substantial contribution to the economic success of industrialized countries and actively influences the economies of developing nations as well.. Therefore, putting more of an emphasis on the agriculture sector will be sensible and appropriate [27]. It is everyone's responsibility to feed the world's expanding population by doubling present production by 2050, as agriculture is the foundation of the global economy [28]. In order to feed a rising population, food supply must increase, and bioenergy has a huge market potential. Furthermore, agriculture needs to change with the environment and use more sustainable and effective production methods [29]. Farmers face challenges including growing more food on less land. In response to the expanding population, farmers and innovators need to collaborate to create solutions that will assist farmers meet increasing production expectations [30], manage weeds, and safeguard crops from them. Utilizing artificial intelligence (AI) in agriculture allows farmers to preserve resources while increasing the production from their land. Over the past few decades, innovative technologies have undergone continual transformation. Utilizing technologies such as robots, the Internet of Things (IoT), drones, and artificial intelligence (AI), a new concept known as "smart agriculture" seeks to monitor and improve agricultural operations [31]. Nowadays, biotechnology companies are using AI/ML technologies to create autonomous robots that can do crucial agricultural chores like crop harvesting far more quickly than people. Weather variations that affect agricultural productivity are among the many environmental variables that machine learning systems track and forecast. The subject of smart agriculture is likewise being significantly impacted by digital transformation [32]. Extreme temperatures can lower wheat yields by 6% per C [33]. As Rubisco activity and hence the photosynthetic process is sensitive to high temperature and stops at temperatures above 35 ◦C [34]. Beyond the methods now employed in agriculture for biomass, developments in remote sensing can directly address the stress physiology of crops affected by water and nutrient constraint. estimation categorization of crop types and mapping of soil properties [35]. Infrastructure with data security is necessary for the application of AI in conjunction with inexpensive multi-channel sensors and remote sensing to gather large amounts of data [36].

Applications of AI are crucial in agriculture to solve issues and ensure more harvests. Climate and environmental factors are crucial to farmers' crop-growing operations (Table 1). In order to boost productivity, AI and machine learning act as predictive analysts by evaluating previously gathered data, determining the best time to plant seeds, defining crop alternatives, and selecting hybrid seeds. According to machine learning (ML) models, cropping patterns may also need to be modified in order to boost yield. Since data collection in data-driven agriculture is still somewhat expensive, IoT and AI have far less of an impact on increasing agricultural output. Production has boosted by as much as 30% thanks to artificial intelligence-based tactics. The most recent automated technologies, such as farm robots and drones, have significantly improved the agro-based sector.

Table 1. AI Application for Monitoring Crop Health.

Utilization	Algorithms	Findings
Monitoring plant growth indicators	Machine learning, threshold segmentation, and CIE	Obtained a really nice outcome
Monitoring grape growth	Computer vision	Accurate barrier and grape bunch identification were made
Nitrogen concentration in rice through diagnosis	MATLAB	Process of changing blades was quantified
Observation of the wheat's heading date	Computer vision	Compared to other methods, the method's absolute inaccuracy is 10.14 percent days
Observation of paddy growth	Remote sensing	Achieved a good result

Crop monitoring and crop health assessment are two of the most important agricultural applications where drone-based solutions are provided in combination with computer vision and artificial intelligence. High-resolution drone cameras take accurate field photographs that can be processed by a convolutional neural network to determine which regions are weed-filled, which crops require additional water, and how stressed the plants are at different stages of growth. The multi-spectral photographs from the drone cameras combine hyper-spectral images with 3D scanning techniques to define the spatial information system utilized for acres of agriculture (Table 2).

Table 2. Global investments in agriculture technology, $m, 2015–2022.

Sectors	2015	2016	2017	2018	2019	2020	2021	2022
Artificial Intelligence	7	152	239	412	379	953	328	217
Digital Media	0	0	0	61	52	26	58	30
Internet of Things	0	0	7	84	55	45	105	91
Robotics	0	2	16	107	125	84	172	2
E-Commerce	0	0	11	14	82	95	398	68
Advanced Material	0	0	0	0	1	0	0	12
Big Data	7	2	61	222	396	189	478	4

Companies that provide agricultural technology, such as Ceres Imaging, Sky Squirrel Technology, and Blue River Technologies, employ robotics and drones in conjunction with computer vision technology to take pictures and do spectrum analysis. To identify irregularities in agricultural yields and irregularities in resource distribution, startups such as Centaur Analytics, Spenser Technologies, and Sen agricultural are utilizing a variety of sensor data. In the examination of agricultural characteristics, sensor data may be a big help. Figure 2 illustrates how AI-based technological developments have enabled farmers to enhance output quality, guarantee a faster time to market for the produced crops, and boost production while utilizing less input. AI machine learning algorithms that have been trained on a range of plant pictures have been able to identify the different levels of stress in plants. This entire process may be broken down into four sequential steps: forecasting, classification, quantification, and recognition in order to make ever-better judgments. In order to maintain their profitability, farmers may now raise their average output per hectare and have more control over the price of food grains.

2.2 AI in Forest Biotechnology

Natural forests have great ecological significance, and wood is becoming a more and more vital resource for civilization. Unfortunately, the present demand cannot be met by these slow-growing woods, which leads to the depletion and degradation of natural resources. Here's where genetic editing and other forms of forest biotechnology can be useful. For instance, there is an urgent need for plantation forests to sustainably supply the world's wood needs, which makes this crucial [37]. Artificial intelligence has a wide range of possible uses, including

- Predictive modeling: AI may be used to evaluate information from drone, satellite, and other sources to forecast the production and growth of various tree species in various places. For optimum production, this can aid in the planting and maintenance of forests [38].
- Disease and pest management: Artificial Intelligence (AI) may be used to evaluate data on the occurrence and dissemination of pests and diseases in forests and forecast their probable effects on tree production and health. In order to preserve forests, this can assist in identifying vulnerable regions and putting preventative measures in place. • Environmental monitoring: AI can determine possible environmental hazards, such as wildfire, and track the health of trees by analyzing data from sensors and other sources [39]. This can assist in determining vulnerable regions and putting policies in place to safeguard forests.
- Resource management: AI may be used to enhance output and reduce waste in forests by optimizing the use of resources like water and fertilizers.
- Inventory management: This can involve the use of AI to analyze data on the location, age, and species of trees, as well as the availability of resources and the demand for different products and services.

2.3 AI in Medical Biotechnology

AI algorithms and software are specifically covered by the European In Vitro Diagnostics Regulation (IVDR). For in vitro diagnostics (IVD) businesses that rely on AI for data analysis and decision assistance, this presents serious difficulties [26]. But if the moral and legal considerations are properly considered and handled, we see AI has the potential to completely transform medical biotechnology by making it possible to identify and create novel medications more quickly, accurately, and economically. The following are some particular applications of AI in medical biotechnology:

- **Identification of drug targets:** AI may be used to examine data from several sources, including protein-protein interactions and genetic data, to find possible therapeutic targets for illness treatment. In order to find patterns and connections that people might not see, machine learning algorithms may be used.
- **Drug screening:** AI may be used to examine data on how well possible medications work against various targets in order to determine which ones are most likely to work. This may entail applying machine learning algorithms to forecast a drug's probability of effectiveness based on both the drug's and the target's attributes.
- **Predictive modeling:** AI may be used to forecast a person's health by analyzing data from several sources, including wearable technology and electronic medical records.

2.4 AI in Healthcare

Artificial intelligence (AI) is a game-changing technology that is changing several industries, including banking, education, transportation, and more. Fundamentally, artificial intelligence (AI) is the creation of computer systems that can carry out operations that normally call for human intelligence, like comprehending natural language, identifying patterns, making decisions, and picking up knowledge from experience [41]. The healthcare industry has been one of the main beneficiaries of AI's promise in recent years, using its skills to improve administrative effectiveness and a number of patient care elements (Figure 1). Healthcare AI integration is more than simply a future idea but a current reality, propelled by notable developments in machine learning algorithms, exponential increases in healthcare data, and improvements in processing power [41,42].

It is difficult to exaggerate the significance of AI applications in healthcare. AI has the ability to completely change the way we manage the operational facets of healthcare delivery, diagnose illnesses, customize therapies for each patient, and track health status in real time. AI-powered diagnostic technologies, for example, are capable of precisely analyzing medical pictures and frequently spotting details that human eyes would miss. Patient outcomes are greatly impacted by the earlier and more precise diagnoses that result from this precision. Similar to this, therapy customization is a step towards genuinely individualized medicine as AI algorithms can search through enormous databases to find trends and forecast which medicines will work best for certain patient profiles.

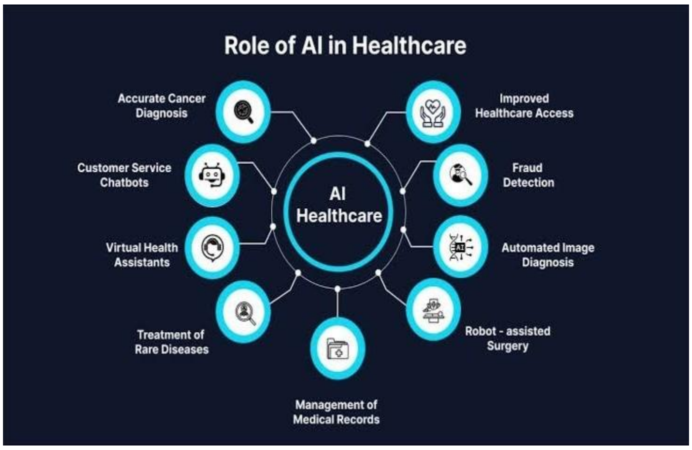

Figure 1: Role of AI in healthcare.

In addition, AI applications are used in patient monitoring, where wearable technology and remote monitoring platforms provide ongoing patient health monitoring, facilitating quick treatments and lowering readmission rates to hospitals. AI can optimize hospital workflows and schedule appointments, among other aspects of healthcare delivery, increasing productivity and patient happiness. [43-45].

This review's scope is purposefully broad but targeted, covering a broad range of AI technologies and their uses in the healthcare industry. This covers, among other things, AI-driven predictive analytics, robotic process automation (RPA), natural language processing (NLP) tools, and machine learning models. The evaluation will examine these technologies in relation to public health efforts, healthcare operations, patient monitoring and care, treatment customisation, and diagnostic support. Although artificial intelligence (AI) has enormous promise in the healthcare industry, this analysis will also outline the limits of existing applications and critically assess the advantages and disadvantages of AI technology in actual healthcare environments. Artificial intelligence has created new opportunities for improving patient care, streamlining healthcare processes, and furthering public health campaigns. The crucial uses of AI in a variety of healthcare-related sectors are thoroughly examined as follows:

Diagnostic Assistance: AI algorithms have greatly increased the precision and effectiveness of illness detection by utilizing information from biometric sensors, genetic testing, and medical imaging. AI-driven technologies, for instance, analyze X-rays, MRIs, and CT scans in medical imaging to precisely identify abnormalities like tumors, fractures, and indications of neurological disorders—often surpassing human capabilities in this regard. By identifying patterns and irregularities that could point to the early stages of illnesses like cancer, these systems use deep learning techniques to enable prompt intervention.

Another area in which AI shines is in the study of genetic data, which provides information on a patient's susceptibility to particular illnesses. Preventative interventions or early therapies customized to a person's genetic composition are made possible by AI algorithms that analyze genetic markers and variants to forecast the likelihood of genetic illnesses. Similar to this, AI applications in biometric data analysis analyze information from wearable technology to track vital signs and identify variations that can indicate health problems, enabling early diagnosis and treatment. [46,47].

(A)Treatment Personalization: AI plays a revolutionary role in therapy personalization, facilitating the transition to precision medicine, in which patient-specific medicines are customized based on their unique traits. AI models determine the best course of therapy for individual patients by analyzing large datasets, such as genetic data, environmental variables, and patient history. This method eliminates side effects, increases therapeutic efficacy, and lessens the trial-and-error process that is frequently involved in selecting the best drug or therapy.

AI in drug development speeds up the process of finding and testing novel medications by forecasting the interactions between various chemical compounds and biological targets. [48-50]

(B) Patient Monitoring and Care: AI has transformed patient care and monitoring, mostly through remote monitoring systems and wearable technologies. These artificial intelligence (AI)-enabled gadgets continually gather health information about patients, including blood pressure, heart rate, glucose levels, and sleep habits, giving real-time insights into their condition. This data is analyzed by sophisticated AI algorithms to find abnormalities that can point to new health problems, allowing for timely medical intervention. Artificial intelligence (AI)-powered solutions also provide tailored health advice and notifications, enhancing patient involvement in their treatment and enabling self-management of long-term illnesses. This proactive approach to patient monitoring lowers readmissions to hospitals, improves treatmentquality, and gives patients the tools they need to actively manage their health [51,52].

(C) Healthcare Operations: Healthcare workers may concentrate on patient care by using AI solutions to automate administrative duties like appointment scheduling, patient triage, and invoicing through process optimization. AI-powered patient flow management systems also guarantee that patients receive care on time, cutting down on wait times and enhancing the quality of healthcare delivery [53,54].

2.5 Public Health and Epidemiology

AI plays a key role in epidemiology and public health by forecasting epidemics, assessing illness trends, and guiding public health initiatives. To monitor and forecast the spread of illnesses, artificial intelligence (AI) systems analyse enormous volumes of data from several sources, such as social media, environmental sensors, and medical records. Public health officials may carry out focused interventions, distribute resources efficiently, and lessen the effects of epidemics thanks to this real-time surveillance. Additionally, AI models aid in the comprehension of intricate public health issues, such how socioeconomic factors affect health outcomes, enabling well-informed policies and intervention tactics. [55,56].

2.6 AI for Climate Resilient Agriculture

Climate Change and Its Impact on Agriculture: One of the most pressing issues facing the world now appears to be climate change, which affects agricultural output, food security, and rural. The impact on livelihoods has been significant. Global temperatures have increased by roughly 1.1°C over pre-industrial levels, according to the Intergovernmental Panel on Climate Change (IPCC), which has led to unpredictable weather patterns, protracted droughts, and heavy precipitation events.[57]. The existing farming systems are directly impacted by these climatic variations due to changes in crop growth cycles, soil fertility, and water availability, which reduces agricultural yields and increases food insecurity [57]. Natural disasters like heat waves, cyclones, and floods have increased in frequency and severity due to climate change, destroying farmlands and upsetting food supply networks [58]. Long stretches of dry weather in South Asia and Africa reduce the amount of agricultural land that can be tilled by lowering groundwater levels and turning land into desert. Moreover, shifting temperature patterns enhance the prevalence of pests and diseases, making staple crops like rice, maize, and wheat more vulnerable [59]. The need for adaptive farming practices to mitigate climate risks and ensure food security for growing global populations is emphasized by these consequences. Adopting climate-resilient agricultural methods is necessary in order to address the problems posed by climate change. Climate-resilient agriculture, or CRA, is an all-encompassing approach that enhances agricultural systems' resistance to climate shocks by integrating modern technologies, sustainable farming methods, and legislative measures [60]. In contrast to traditional mitigation strategies that just aim to reduce carbon emissions, CRA emphasizes improved soil health, climate-tolerant crop production, and the efficient use of natural resources [59,60]. A number of flexible strategies have been proposed to encourage climate resilience in farming. These include integrated pest management, precision irrigation, agroforestry, and conservation agriculture, all of which help to preserve soil moisture, lower greenhouse gas emissions, and boost overall output [60].

Conclusion & Future Perspectives: Taken together the present compilation with the previous relevant studies [61-63], it is well concluded that Edge AI, block chain-based agricultural intelligence, and federated learning are some of the emerging concepts highlighted as possibly advantageous for future climate-resilient farming systems directly and/or indirectly impacting on health care and food system.

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