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ARTIFICIAL INTELLIGENCE IN CLIMATE SMART IN AGRICULTURAL: TOWARD A SUSTAINABLE FARMING FUTURE

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ABSTRACT

This paper explores the connections between artificial intelligence and climate smart agricultural change research as a whole and its usefulness in adaptation efforts in smart agricultural technologies. In article increased attention is currently being paid to the use of smart technologies.
The article provides an analysis of the prospects for the use of artificial intelligence technologies and Climate-Smart Agriculture. At the preparatory stage, an analysis of publications in the Woofs network was carried out, which allows specifying the essence and scope of artificial intelligence technologies in climate smart agriculture.
The authors considered divided into four important components which include: the management of crops, farms, livestock and aquaculture to achieve a near-term balance in food security and livelihoods; the management of landscapes and ecosystems top reserve ecosystem services that are critical for agricultural development, food security, adaptation, and mitigation; enable better farm and land management by providing services on climate impacts and mitigation actions to managers of these resources; enhancing the derivable benefits of Climate-Smart Agriculture through demand-side measures and value chain interventions. Accordingly, Climate-Smart Agriculture and artificial intelligence aims to achieve the objectives of increasing productivity and incomes sustainably, making agriculture adaptive to the changing climate, and where possible cost-effective.

Keywords: *Sustainability, artificial intelligence, climate smart in agricultural, machine learning, artificial intelligence technologies*
JEL classification: Q10; O10; Q01
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INTRODUCTION

Artificial Intelligence (AI) is believed to have a significant potential use in tackling climate change. Agriculture is the oldest and most dynamic occupation throughout the world (Eli-Chukwu, 2019; Kaur & Sidhu, 2020; Marco et al., 2021).

According to experts (Matyushenko et al., 2020; Gryshova et al., 2019; Nassivera et al., 2017; Bao & Xie, 2022; Kurgat et al., 2020; Ma et al., 2022; Delcheva, Nencheva &Penev, 2021; Lazarova et al., 2023; Zagorodnya, Chernukha & Petrova, 2020; Todorov, Aleksandrova & Ismailov, 2023) since the population of world is always increasing and land is becoming rare, there evolves an urgent need for the entire society to think inventive and to find new affective solutions to farm.

The importance of addressing climate change in agriculture cannot be overstated. Agriculture is inherently dependent on favorable climatic conditions, including temperature, precipitation, and sunlight, for optimal crop growth and livestock production. However, climate change is causing shifts in these conditions, leading to increased variability, extreme weather events, and long-term changes in temperature and rainfall patterns. These changes pose significant challenges and risks to agricultural systems worldwide. (Gulzar, Abbas & Waqas, 2020; Klerkx, Jakku, Labarthe, 2019; Marco et al., 2021; Subeesh & Mehta, 2021)

Agriculture is the primary source of food for the growing global population. Climate change threatens food security by disrupting crop yields, reducing the availability of water for irrigation, and increasing the prevalence of pests and diseases (Krastanova et al., 2022). Adapting agricultural practices to climate change is crucial to ensure a stable and sufficient food supply for current and future generations (Ma et al., 2022; 2021; Vijayakumar & Balakrishnan, 2021).

The livelihoods of millions of farmers depend on agricultural activities. Climate change-induced events such as droughts, floods, and heatwaves can have devastating effects on crop yields, livestock productivity, and farm incomes. Addressing climate change in agriculture is essential for preserving rural livelihoods, reducing poverty, and ensuring sustainable rural development. (Veroustraete, 2015; Wang, Wang & Zhang, 2019)

Agriculture is intricately connected to the environment. Unsustainable agricultural practices contribute to greenhouse gas emissions, deforestation, soil degradation, and water pollution. By adopting climate-smart agricultural practices, such as conservation agriculture, agroforestry, and precision farming, we can mitigate the environmental impact of agriculture and promote sustainable land and resource management (Ma et al., 2022; Toleuuly et al, 2020; Tielkiniena et al., 2020)

LITERATURE REVIEW

Agricultural ecosystems are home to diverse flora and fauna and provide various ecosystem services. Climate change affects biodiversity by altering habitats, disrupting pollination patterns, and increasing the risk of invasive species. Sustainable farming practices that consider climate change can help preserve biodiversity, protect ecosystem services, and maintain the resilience of agricultural landscapes (Marco et al., 2021; Ma et al., 2022; Tielkiniena et al., 2020).

Climate change is characterized by increased variability and uncertainty. By addressing climate change in agriculture, farmers can enhance their resilience to climate-related risks. Adaptation measures, such as utilizing drought-tolerant crop varieties, implementing efficient irrigation systems, and adopting climate-smart technologies, can help farmers cope with changing conditions and minimize production losses (Wang, Wang & Zhang, 2019).

Agriculture is a significant contributor to greenhouse gas emissions, primarily through methane from livestock and nitrous oxide from fertilizers. By adopting climate-smart practices, such as improved nutrient management, precision fertilization, and methane capture technologies, agriculture can contribute to mitigating climate change by reducing emissions and enhancing carbon sequestration in soils (Eli-Chukwu, 2019).

Climate-Smart Agriculture (CSA) is an approach to transform and reorient agricultural production systems and value chains to support sustainable development and food security in the face of climate change. CSA is a set of practices that should be adapted and applied within a specific approach that includes various elements built into specific contexts and adapted to meet local needs. To enhance food security in the face of climate change, we will need agriculture systems that are more productive, use inputs more efficiently, and are more resilient to a wide and growing range of risks. (Yessengeldin et al, 2019; Ma et al., 2022; Wang, Wang & Zhang, 2019; Ramazanov & Petrova, 2020).

This will mean changing the way land, soil, water, and other inputs are managed. But because agriculture varies from place to place, and climate change will impact each location differently, climate-smart agriculture needs to respond to local conditions. It is not a one-size-fits-all approach to agriculture, but rather a framework to be applied and adapted – a paradigm shifts in thinking and action. Agriculture is now turning to artificial intelligence (AI) have been employed in agriculture over a long period of time, alongside other advanced computing technologies.

Climate smart agriculture (CSA) which involves the integration of Artificial Intelligence (AI) –this emerging agricultural paradigm that is foreseen to be the main driver of agriculture as the Artificial Intelligence (AI) is believed to have a significant potential use in tackling climate change. This paper explores the connections between AI and climate smart agricultural change research as a whole and its usefulness in adaptation efforts in smart agricultural technologies (Eli-Chukwu, 2019; Gulzar, Abbas & Waqas, 2020; Klerkx, Jakku & Labarthe, 2019).

Climate-Smart Agriculture (CSA) is an approach that aims to address the challenges posed by climate change in agriculture while promoting sustainable and resilient farming practices. It combines three key principles: increasing agricultural productivity, enhancing adaptation to climate change, and reducing greenhouse gas emissions. The objectives of Climate-Smart Agriculture are as follows:

The first objective of CSA is to improve and sustain agricultural productivity to meet the growing global food demand. This involves implementing practices that optimize resource use, enhance soil fertility, and promote efficient crop and livestock management techniques. By increasing productivity, CSA aims to ensure food security and support rural livelihoods.

CSA recognizes that climate change is already affecting agricultural systems and aims to enhance their resilience and adaptive capacity. The objective is to help farmers and farming communities cope with the impacts of climate change, such as increased variability in weather patterns, extreme events, and changing pest and disease dynamics. CSA promotes the adoption of climate-resilient varieties, diversified cropping systems, and improved water management practices.

Agriculture is a significant contributor to greenhouse gas (GHG) emissions, particularly methane (CH4) from livestock and nitrous oxide (N2O) from fertilizers and soil management practices. The objective of CSA is to reduce these emissions by promoting practices that minimize the release of GHGs and enhance carbon sequestration in soils and vegetation. This includes precision nutrient management, agroforestry, conservation agriculture, and the use of renewable energy source (Klerkx, Jakku & Labarthe, 2019; Veroustraete, 2015).

As rightly noted by B.K. Kurgat (Kurgat et al., 2020), CSA seeks to ensure long-term food security and contribute to sustainable development goals. It aims to improve access to nutritious food, reduce poverty, and promote sustainable rural livelihoods. By promoting sustainable and climate-resilient farming practices, CSA supports economic growth, social well-being, and environmental sustainability.

On the other hand, CSA emphasizes the efficient use of resources such as water, energy, and nutrients to minimize waste and environmental impact. It encourages the adoption of precision farming techniques, water-saving irrigation systems, and integrated nutrient management practices. By optimizing resource use, CSA aims to conserve natural resources and reduce the carbon and water footprints of agriculture.

Knowledge sharing, capacity building, and collaboration among stakeholders are essential components of CSA. It involves the exchange of information, best practices, and technologies to support farmers in implementing climate-smart solutions. CSA encourages partnerships between farmers, researchers, policymakers, and private sector entities to drive innovation, improve access to resources, and scale up climate-smart agricultural practices.

Artificial intelligence (AI) has numerous applications in agriculture and animal farming, ranging from precision management practices to improved monitoring and decision-making. Here are some key applications of AI in agriculture and animal farming:

AI-powered systems can analyze images of crops to detect diseases, nutrient deficiencies, and pest infestations. By using computer vision and machine learning algorithms, AI can identify visual patterns associated with crop health issues. This enables farmers to take early action and implement targeted treatments, reducing crop losses and optimizing resource usage.

AI plays a vital role in precision agriculture, optimizing resource allocation and improving crop yields. AI algorithms analyze data from multiple sources, including sensors, drones, and satellites, to provide insights into soil conditions, weather patterns, and crop growth. This information helps farmers tailor irrigation, fertilization, and pesticide application to specific areas within a field, minimizing input waste and maximizing productivity (Kaur & Sidhu, 2020).

AI-powered machinery and robotics automate labor-intensive tasks in farming and animal management. As rightly noted by Ngozi Clara Eli-Chukwu (Eli-Chukwu, 2019), autonomous equipment can perform planting, harvesting, and weeding with precision, improving efficiency and reducing the need for manual labor. In animal farming, robots can automate feeding, monitoring, and milking processes, ensuring consistent and optimal care for livestock. AI technologies assist in monitoring the health and welfare of livestock. Sensors and cameras collect data on animal behavior, feed consumption, and health parameters. AI algorithms analyze this data, enabling early detection of health issues, predicting disease outbreaks, and optimizing feeding and breeding practices. This leads to improved animal welfare, increased productivity, and reduced veterinary costs.

AI can analyze data on animal nutrition, feed composition, and performance to optimize feed formulation and feeding practices. By considering factors such as animal health, growth stage, and nutrient requirements, AI algorithms can generate customized feed plans. This enhances feed efficiency, minimizes waste, and reduces environmental impacts associated with animal farming.

AI can contribute to disease surveillance and outbreak prediction in animal farming. By analyzing data from various sources, including veterinary records, environmental factors, and animal health indicators, AI algorithms can identify patterns and predict disease outbreaks. Early detection and proactive measures enable farmers to implement control strategies, minimizing the spread of diseases and reducing economic losses.

AI can aid in environmental monitoring, including soil health assessment, water quality monitoring, and biodiversity monitoring. AI algorithms process data from sensors and other sources to identify environmental risks and optimize resource usage. This promotes sustainable farming practices, reduces environmental impact, and supports the conservation of natural resources (Kurgat et al., 2020).

AI-powered data analytics tools assist farmers in making informed decisions. AI algorithms process large volumes of data, including historical records, weather data, and market trends, to provide actionable insights. This helps farmers optimize planting schedules, manage inventory, predict market demand, and make data-driven decisions to improve productivity and profitability (Gulzar, Abbas & Waqas, 2020; Klerkx, Jakku & Labarthe, 2019; Ma et al., 2022; Veroustraete, 2015).

Mitigating climate risks and building resilience are essential in both agriculture and animal farming. Artificial intelligence (AI) offers several applications that contribute to these goals. Here are key applications of AI in agriculture and animal farming for mitigating climate risks and building resilience:

AI algorithms analyze historical climate data, satellite imagery, and real-time weather data to develop climate models and predict future climate patterns. These predictions help farmers and animal producers anticipate and plan for climate-related risks, such as extreme weather events, temperature fluctuations, or disease outbreaks. By incorporating AI-generated climate forecasts, stakeholders can make informed decisions about management practices, animal welfare, and adaptation strategies (Eli-Chukwu, 2019).

AI technologies assist in monitoring and managing livestock by analyzing data collected from sensors, cameras, and wearable devices. Machine learning algorithms can detect and analyze behavior patterns, health indicators, and environmental conditions. This enables early detection of diseases, distress signals, or abnormal behavior in animals. By identifying such issues promptly, appropriate actions can be taken to mitigate risks, ensure animal welfare, and prevent the spread of diseases.

AI algorithms analyze data on animal nutrition, feed composition, and performance to optimize feed formulation and feeding practices. By considering factors such as animal health, growth stage, and nutrient requirements, AI can generate customized feed plans. This enhances feed efficiency, minimizes waste, and reduces the environmental impact of animal farming. Optimized nutrient management helps mitigate greenhouse gas emissions from livestock and promotes sustainable resource use (Koshkalda et al., 2020).

AI supports breeding programs that aim to develop climate-resilient livestock. By analyzing genetic data, environmental conditions, and performance records, AI algorithms can identify genetic markers associated with desirable traits such as heat tolerance, disease resistance, or feed efficiency. This knowledge assists in selective breeding, enhancing the resilience of animal populations to climate-related stresses and reducing vulnerability to climate risks.

AI technologies can integrate real-time data on weather, climate, and animal health to develop early warning systems for climate-related risks. By analyzing these data streams, AI algorithms can provide timely alerts and recommendations to farmers and animal producers. This helps them take preventive measures, such as adjusting management practices, sheltering animals, or implementing biosecurity protocols, to mitigate risks and minimize losses (Bao & Xie, 2022; Ma et al., 2022; Tielkiniena et al., 2020).

AI-powered decision support systems provide farmers and animal producers with real-time insights and recommendations. By integrating data from multiple sources, including weather forecasts, environmental sensors, and animal health records, AI algorithms assist in making informed decisions related to climate risks and resilience-building strategies. This includes recommendations on adaptive management practices, resource allocation, and risk mitigation measures.

AI contributes to disease surveillance and control in animal farming. By analyzing data on disease prevalence, environmental factors, and animal health indicators, AI algorithms can identify patterns and predict disease outbreaks. Early detection allows for prompt response and targeted interventions, such as vaccination, quarantine, or treatment, reducing the spread and impact of diseases on animal populations (Kurgat et al., 2020; Tielkiniena et al., 2020).

MATERIALS AND METHODS

Many aspects related to the implementation and use of AI technologies in agriculture economy, theoretically and methodically are not developed. The conceptual apparatus has not been sufficiently developed, and the consequences of using artificial intelligence technologies have been little studied. This explains the choice of topic, object, subject, purpose and objectives of the study. In the course of the study, a bibliometric method was used, which allows collecting information about publications for its further generalization.

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In this study, an in-depth scanning texts to select keywords, then analysis of publications in scientometric databases was carried out.

To assess the possibilities of applying technologies AI in agriculture used toolkit SWOT analysis. Universal tricks of this method made it possible to identify strengths and weaknesses, to identify opportunities and threats of application of AI technologies in climate smart in agricultural. We also used the economic-statistical analysis and other methods of scientific research, due to the specific objectives of the study.

RESULTS

Currently, climate-oriented agriculture in Ukraine is making the transition to digital technologies. According to BI Intelligence Research forecasts, global spending on smart agricultural technologies and systems, including artificial intelligence and machine learning, will triple by 2025, reaching $15.3 billion.

Artificial intelligence, machine learning and Internet technologies, which provide real-time data for algorithms, significantly increase the efficiency of agricultural enterprises, crop yields and reduce food production costs. According to UN analytics, by 2050 the world's population will increase by another 2 billion people. This requires a 60% increase in food production. According to the Economic Research Service of the United States Department of Agriculture, the cultivation, processing and logistics of food in the country is valued at $1.7 trillion. Artificial intelligence and machine learning just show the potential to help meet the expected food needs in 20-30 years.

Imagine that in a large agricultural holding on an area of several tens of thousands of hectares, there are at least 40 main processes that need to be monitored, improved and controlled at the same time. Understanding how weather, seasonal rainfall, bird and insect migration, fertilizer use for various crops, planting and irrigation cycles affect yields is an ideal task for machine learning. How successful a harvest can be financially, more than ever, depends on various excellent data. This is why farmers, cooperatives and climate-smart agriculture development companies are doubling down on data-driven measures. They are also expanding the use of artificial intelligence and machine learning to improve the yield and quality of agricultural products.

On the basis of theoretical generalization, methods of analysis and synthesis, the practices of implementing artificial intelligence and climate smart agriculture were investigated. When conducting research, informational materials were used materials, including from sites that present research results and information on the implementation of artificial intelligence in climate smart agriculture.

At the final stage, SWOT analysis tools were used to determine the state and prospects for the use of artificial intelligence technologies in climate smart agriculture. This made it possible to identify strong parties, outline promising opportunities for the future, arising from the use of artificial intelligence in climate smart agriculture (table 1).

Table 1. SWOT analysis of the using AI technologies in agriculture

Strengths	Weaknesses
AI enables the analysis of large and complex datasets, facilitating data-driven decision-making processes in CSA.	The effectiveness of AI in CSA relies on the availability and quality of data, which may be limited or inconsistent in some regions or farming systems.
AI technologies, such as machine learning algorithms, can optimize resource allocation, crop management, and yield prediction, leading to increased efficiency.	Implementing AI technologies requires specialized knowledge and skills, posing a challenge for farmers and stakeholders with limited technical expertise.
AI enables precision agriculture practices by providing accurate and real-time information on crop health, soil conditions, and climate parameters.	Integrating AI systems and infrastructure may involve high initial costs, especially for small-scale farmers or resource-constrained regions.
AI technologies can automate repetitive tasks, reducing labor requirements and increasing productivity in CSA.	The use of AI raises ethical concerns related to data privacy, algorithmic bias, and unintended consequences, which require careful attention and regulation.
AI-based systems can identify early signs of pests, diseases, or climate risks, allowing for timely intervention and mitigation.	Access to AI technologies and resources may be limited, particularly in developing regions, hindering widespread adoption in CSA.
Opportunities	**Threats**
AI can assist in developing adaptive strategies and risk management techniques to cope with the impacts of climate change on agriculture.	AI applications rely on large volumes of sensitive agricultural data, increasing the risk of data breaches and unauthorized access.
Improved Resilience: AI technologies can help build resilient farming systems by providing real-time insights, early warning systems, and adaptive management practices.	Biased data or algorithmic biases in AI systems can perpetuate inequalities and marginalize certain farmers or regions.
AI can facilitate knowledge sharing and collaboration among farmers, researchers, and stakeholders, enabling the exchange of best practices and innovative solutions.	Overreliance on AI technologies without proper fallback measures may pose risks if there are technical failures, power outages, or limited connectivity.
AI algorithms can be tailored to specific farming conditions, allowing for personalized recommendations and solutions based on individual farm requirements.	Resistance to change, lack of awareness, and cultural barriers can hinder the widespread adoption of AI technologies in CSA.
Increasing recognition of the potential of AI in CSA can lead to policy support and investment in research and development, fostering innovation and adoption.	The cost of implementing AI technologies may create disparities, exacerbating the digital divide and excluding resource-constrained farmers or regions.

As a result of the SWOT analysis of the use of AI technologies in climate-smart agriculture, several key observations and insights can emerge. Here are some possible outcomes:

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- The analysis highlights the strengths of using AI technologies in climate-smart agriculture, such as data-driven decision-making, enhanced efficiency, and early disease detection. These strengths can be harnessed to optimize resource management, improve crop yield, and mitigate climate risks.

- The identified weaknesses, such as data quality and availability, technical expertise, and cost of implementation, can guide efforts to address these challenges. Steps can be taken to improve data collection and management systems, provide training and capacity-building programs, and explore cost-effective AI solutions for wider adoption.

- The analysis identifies opportunities to leverage AI in climate-smart agriculture, including improved resource management, climate adaptation, and precision farming. Stakeholders can focus on developing and implementing AI-driven tools, systems, and practices that align with these opportunities to enhance sustainability and resilience in agriculture.

- The analysis acknowledges potential threats, such as data privacy and security concerns, algorithmic biases, and social acceptance issues. This understanding allows for the development of robust frameworks, regulations, and ethical guidelines to mitigate risks, build trust, and ensure responsible and equitable AI adoption in agriculture.

- The SWOT analysis serves as a basis for strategic decision-making in the integration of AI technologies in climate-smart agriculture. It helps stakeholders prioritize actions, allocate resources effectively, and foster collaborations to maximize the benefits of AI while minimizing potential drawbacks.

Application of artificial intelligence in climate smart agriculture allow analyzing and processing large amounts of information, combining various information resources on one platform, controlling and reducing production risks, meeting the information needs of a wide range of stakeholders, from the state to the end user, as well as ensuring security in cyberspace. An important role in the climate smart agriculture is played by the resource potential of people employed in smart agriculture. Special attention is paid to the development of research centers, training courses, where an in-depth study of modern high-precision agricultural technologies is conducted.

To analyze the survey on the application of artificial intelligence (AI) in climate-smart agriculture, we were examining the responses and draw insights based on the provided data. Let's analyze the data you provided (table 2).

Table 2. Familiarity with AI in Climate-Smart Agriculture

Level of Familiarity	Number of Respondents	Percentage, %
Very Low	50	20
Low	100	40
Moderate	60	24
High	30	12

Very High	20	4
Total	260	100

Very Low Familiarity: 50 respondents (20%) reported very low familiarity with AI in climate-smart agriculture. This indicates that a significant portion of the respondents lacks knowledge and understanding of AI in the context of sustainable agriculture. Additional efforts are needed to educate and raise awareness among this group about the potential benefits and applications of AI in climate-smart agriculture.

Low Familiarity: 100 respondents (40%) reported low familiarity with AI in climate-smart agriculture. This suggests a relatively larger group with some awareness of AI but limited knowledge and practical experience. It is essential to focus on providing training, resources, and information to this segment to enhance their familiarity and encourage the adoption of AI solutions in agriculture.

Moderate Familiarity: 60 respondents (24%) indicated a moderate level of familiarity with AI in climate-smart agriculture. This group possesses a reasonable understanding of AI and may have some experience in utilizing AI applications in the agricultural sector. Building upon their existing knowledge, it would be beneficial to provide further training and support to help them maximize the potential of AI in their agricultural practices.

High Familiarity: 30 respondents (12%) reported a high level of familiarity with AI in climate-smart agriculture. This smaller group demonstrates a strong understanding of AI concepts and techniques, indicating that they might already be actively using AI in their agricultural practices. Leveraging their expertise and experience, it would be valuable to encourage knowledge sharing and collaboration with other stakeholders to drive further innovation in this field.

Very High Familiarity: 20 respondents (4%) reported a very high level of familiarity with AI in climate-smart agriculture. This group likely consists of experts or advanced researchers who possess extensive knowledge, experience, and engagement with AI applications in the agricultural domain. Their insights and expertise can be utilized to develop advanced AI-driven solutions and guide future research and development efforts.

Recently, there has been a sharp increase in the number of publications of the Web of Science database on the application of these technologies in agriculture. In the course of the study, a total of 889 such an article published from 2017 to 2022. At At the same time, the largest increase was observed in 2022 and in addition, an analysis was made of the number of publications in the largest scientific citation database WoS in the context countries (Table 3).

Summarizing the data of some artificial intelligence technologies used in agriculture, we can highlight some of their common characteristics. AI technologies used in climate-smart agriculture have a number of significant features, namely:

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Table 3. Number of publications in the WoS database by country

Countries	Number of publications
China	265
USA	168
Australia	77
Spain	43
Italy	62
Germany	49
Jupan	77
Franch	69
Greece	79
Total	889

AI relies on large volumes of data collected from various sources, including weather stations, sensors, satellites, and historical records. By analyzing and processing this data, AI technologies can provide valuable insights and support data-driven decision making in agriculture. This allows farmers to optimize resource allocation, implement precision farming techniques, and make informed choices based on real-time information. These are technical solutions, primarily software and hardware tools for performing certain agricultural work or forecasting development of the industry depending on various factors (climate, soil conditions, rainfall, prices for market). AI technologies are often used together with robotics, here we can talk about their interaction. So, the robot provides movement, manipulation of objects and tools, and AI technologies, in in turn, carry out orientation in space, choose the optimal tools for the robot when performing a certain job, recognize obstacles and objects, etc.

CONCLUSION

These applications of AI in agriculture and animal farming illustrate its potential to enhance efficiency, productivity, and sustainability. By leveraging AI technologies, farmers can optimize resource usage, improve decision-making, and mitigate risks, ultimately contributing to more sustainable and resilient agricultural practices.

Climate-Smart Agriculture aims to create a sustainable and resilient agricultural system that can adapt to and mitigate the impacts of climate change. By embracing the principles and objectives of CSA, farming communities can enhance productivity, build resilience, reduce greenhouse gas emissions, and contribute to sustainable development goals.

By leveraging the power of AI in agriculture and animal farming, stakeholders can enhance their capacity to mitigate climate risks and build resilience. The applications of AI enable better decision-making, adaptive practices, and early interventions, leading to more sustainable and climate-resilient agricultural systems.

In conclusion, artificial intelligence (AI) has the potential to revolutionize and contribute to climate-smart agriculture, leading us toward a sustainable farming future. By harnessing the power of AI, farmers and agricultural stakeholders can make more informed decisions, optimize resource utilization, and mitigate the negative impacts of climate change on food production.

AI technology enables the collection and analysis of vast amounts of data, including weather patterns, soil conditions, crop growth stages, and pest infestations. By processing and interpreting this data, AI systems can generate valuable insights and provide recommendations to farmers in real-time. This empowers farmers to optimize their practices and make more sustainable choices.

One key application of AI in climate-smart agriculture is precision farming. AI-driven tools, such as remote sensing and satellite imagery, can accurately monitor crop health and identify areas requiring specific interventions. This enables targeted irrigation, fertilization, and pest control, minimizing the use of resources and reducing environmental impact.

AI also plays a crucial role in climate modeling and prediction. Machine learning algorithms can analyze historical climate data and identify patterns, allowing for the creation of accurate climate models. These models can help farmers anticipate climate-related risks, such as droughts or floods, and take proactive measures to adapt their farming practices accordingly.

Furthermore, AI can support the development of climate-resilient crop varieties. By analyzing genetic data and simulating plant breeding processes, AI algorithms can expedite the identification and development of crops that are more tolerant to extreme weather conditions or resistant to pests and diseases. This not only enhances crop yields but also reduces the reliance on chemical inputs.

Collaboration and knowledge sharing are essential for the successful integration of AI in climate-smart agriculture. Governments, research institutions, and technology companies need to work together to ensure that AI solutions are accessible, affordable, and tailored to the needs of farmers in different regions. Furthermore, data privacy and security concerns must be addressed to foster trust and facilitate the widespread adoption of AI technologies.

Future technical development will help businesses interested in enhancing AI-based goods or services, such as training data for smart agriculture, drones, and automated machine manufacturing, allowing the globe to address challenges with food supply for a growing population. The future of AI in climate smart agriculture will require a significant focus on universal access because the majority of cutting-edge technology is only utilized on big, well-connected farms. The future of ML-automated agricultural goods and data science in farming will be secured by extending reach and connection to small farms in distant regions worldwide. Because AI maximizes resource utilisation and efficiency and, to a significant part, resolves the resource and labour shortage, it will be helpful and effective in the agriculture industry. This technology will also play an essential role in research and development in the field of horticulture.

The authors made recommendation on how to helping farmers AI-enabled technologies use data like temperature, precipitation, wind speed, and solar radiation in combination with ML algorithms and images taken by satellites and drones to predict weather conditions, analyse crop sustainability, and evaluate farms for the presence of diseases or pests and inadequate plant nutrition. Farmers with Wi-Fi connectivity may use AI applications to receive an AI-tailored farm plan. Using AI-driven solutions that enhance output and income without diminishing priceless natural resources, farmers can fulfil the global need for higher food supply and profitability. Farmers can use AI to get real-time insights from their fields, identifying areas that need irrigation, fertilisation, or pesticide treatment. Innovative in climate smart agriculture practices such as vertical agriculture may help increase food production while using lesser resources. As a result, herbicides are used less, harvest quality is improved, profits are increased, and significant cost savings are realised. AI ools collect high-resolution aerial images and data on irrigation systems needed for the fields. AI aids in the detection of soil issues such as clogs and leaks. It assesses and rates the soil's poor condition; AI assists in increasing farm productivity. The net output from the field is improved by automated and autonomous farming operations, AI-enabled productions, and yield management. AI-assisted picking, packing, and sorting enhances food production, packaging, and sorting. Farmers benefit from its assistance in comprehending agricultural data insights related to temperature, precipitation, wind speed, and solar radiation. Farmers' problems, such as climate change and insect and weed infestations that lower yields, may be resolved through AI solutions. AI will be used in climate smart in agricultural to improve the entire agriculture process.

This work explored the possibilities creation and implementation of such AI technologies that would make current and future climate smart agriculture more sustainable. The analysis showed that although the technology AI is developing and becoming an integral part of agriculture. We still need to find ways to embed and develop AI in our Climate smart agriculture taking into account the requirements of sustainability, as well as minimize negative social ecological effects of ecosystem sustainability.

Finally, in the context of smart and sustainable climate smart in agriculture, artificial intelligence is an emerging area of research. Further theoretical and empirical research is needed considering this phenomenon from different angles and within different disciplines to create the knowledge base that politicians, managers, farmers need to were able to take informed implementation decisions AI in agriculture and offset the inevitable problems that will follow. This will not be an easy task. The fusion of artificial and human intelligence is the next a big challenge for climate smart sustainable development.

In conclusion, the integration of artificial intelligence in climate-smart agriculture holds great promise for a sustainable farming future. By leveraging AI's capabilities, farmers can make informed decisions, optimize resource allocation, reduce environmental impact, and build resilience against the challenges posed by climate change. As AI technologies continue to advance and become more accessible, they have the potential to transform the agricultural sector, ensuring food security and sustainable farming practices in the face of a changing climate.

Addressing climate change in agriculture is not only a necessity but also an opportunity. By embracing sustainable farming practices, harnessing technological advancements like artificial intelligence, and promoting policy support, we can create a resilient and sustainable agricultural sector. This not only helps mitigate climate change but also ensures food security, supports rural communities, preserves biodiversity, and promotes environmental stewardship for a more sustainable future.

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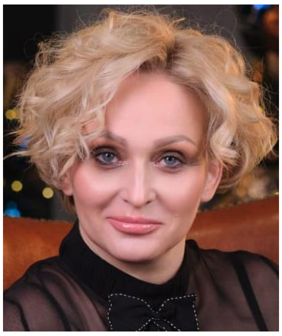

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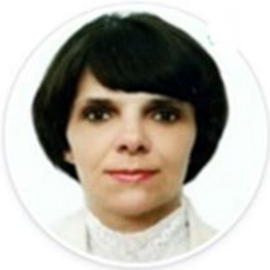

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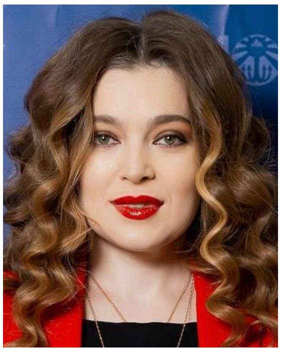

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