Chapter

Sustainable Artificial Intelligence Solutions for Agricultural Efficiency and Carbon Footprint Reduction in India

Simran Ahuja and Pooja Mehra

Abstract

By boosting productivity, cutting waste, and raising yields, Artificial Intelligence (AI) has the potential to revolutionise Indian agriculture. It is crucial to consider the complete life cycle of AI systems to reduce the carbon footprint of AI in agriculture. Though the impact of artificial intelligence (AI) is always assumed to be positive in reducing carbon emissions, the forecasting analysis based on the exponential smoothing model and life cycle assessment (LCA) predicts that AI will decrease carbon emission in agriculture by 2030. To move forward, some policy recommendations include promoting energy-efficient AI hardware, adoption of renewable energy, optimizing AI algorithms for energy efficiency, supporting precision agriculture (PA), and embracing circular economy practices. The way to achieve sustainable agriculture with the combination of smart agriculture is through Precision farming, which has the potential to transform Indian agriculture, enhance food security and help farmers adapt to climate change while increasing efficiency. Data-driven decision in crop management can lessen climate change effects and reduce vulnerability to extreme weather events. Overall, lowering the carbon footprint of AI in agriculture would necessitate a combination of legislative initiatives that support energy-saving technologies, renewable energy, and environmentally friendly farming methods.

Keywords: sustainable agriculture, carbon footprint, artificial intelligence, smart farming, precision agriculture

1. Introduction

Agriculture constitutes the most significant part of the Indian economy [1]. It is one of the mainstays of the Indian economy, employing about 50% of the workforce and contributing about 17% to the country's gross domestic product (GDP). India has a diverse agricultural sector, with a wide range of crops, ranging from traditional subsistence crops to high-value cash crops. India's agriculture has to face a number of difficulties, such as low productivity, dispersed landholdings, inefficient resource utilisation, and limited infrastructure. Nevertheless, the government has started a number of programmes to address these issues and advance sustainable agriculture. These include programmes to advance organic farming, enhance irrigation, and give farmers more access to loans and markets [2].

It is essential that agricultural practices be evaluated in order to propose novel solutions for sustaining and enhancing agricultural activity as the world's population grows geometrically. Other technological advancements, such as big data analytics, robotics, the Internet of Things (IoT), the accessibility of inexpensive sensors and cameras, drone technology, and even widespread Internet connectivity on geographically separated fields, will make it possible to apply AI to agriculture. AI systems will be able to predict which crop to plant in a given year with the best dates for sowing and harvesting in a particular area by analysing soil management data sources such as temperature, weather, soil analysis, moisture, and historic crop performance. This will increase crop yields and reduce the use of water, fertilisers, and pesticides. By utilising AI technologies, it may be possible to lessen the impact on natural ecosystems and improve worker safety, which will help to keep food prices low and guarantee that food production will keep up with the growing global population.

Artificial intelligence in agriculture has the potential to cut carbon emissions from agricultural activities and revitalise the entire economy. Global warming has made India's agricultural sector more expensive, time-consuming, and out of date. Given the idiosyncrasies of small-scale farmers, conventional farming practices, a lack of credit, storage facilities, and the risk-seeking mindset of decision-makers, the deployment of AI technology in Indian agriculture is still a distant dream. For sustainable and green agriculture to be realised, AI solutions must be supplied at the farmers' doorstep in their native tongue, with appropriate training, input support, and in a collective/cooperative manner. Artificial intelligence (AI) has the potential to dramatically improve production and efficiency in Indian agriculture, but it also raises questions about how it may affect the environment, notably in terms of carbon emissions. The increasing use of AI in Indian agriculture is contributing to a growing carbon footprint, which threatens to exacerbate the climate crisis, and urgent measures are needed to mitigate these emissions while maintaining the benefits of AI for sustainable agriculture.

With the large-scale mechanisation of the agricultural sector in the twentieth century, labour was increasingly replaced by machinery, land productivity increased, and economies of scale were achieved [3]. Farmers were able to manage larger fields and farms as a result of the transition from labour- to capital-intensive farming. The Green Revolution, which began in the middle of the twentieth century, increased productivity through the use of genetically enhanced cultivars, artificial chemical fertilisers, and crop-damaging pesticides. In many regions of the world, these developments favoured the growth of bigger and more consistently managed fields. Contrarily, prior to the advent of agricultural mechanisation, farmers could modify their within-field management in primarily manual ways to take into account variations in yield potentials, topography, soil characteristics, nutrient demands, and both abiotic (such as weather) and biotic (such as pest and weed infestation) stresses. But by adopting consistent practices and achieving economies of scale through mechanisation, farmers gave up the ability to effectively manage the geographical and temporal variety of their fields. Precision farming technologies became commercially available in the early 1990s. Precision farming addresses the challenge of tailoring management to site, crop, and environmental traits [4] and promotes the use of new technologies and data to address the heterogeneities of a field. As a result, Precision farming includes standardised techniques to lessen the unknowns associated with the information base for farm management decisions and allows for temporal and site-specific farm management even for highly mechanised and

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extensive agricultural systems. In other words, Precision farming enables big farms to customise management the same way small farms do. It is a paradigm shift since the field is viewed as a diverse entity that can be managed and treated selectively.

While artificial intelligence (AI) has the potential to reduce agriculture's carbon footprint, it is crucial to make sure that the energy needed to power AI systems comes from sustainable sources, such as solar or wind power, to reduce the emissions related to electricity generation. Moreover, the extraction and processing of raw materials necessary for the creation of AI technology might have negative environmental effects including habitat destruction and pollution. As a result, it is crucial to produce AI hardware from ecologically safe and sustainable components [5].

Based on the above review, the study focuses on the following objectives that are

- To study the effect of AI on the agricultural sector through life cycle assessment (LCA) in India.
- To forecast the trend of carbon footprint for the coming years and its impact on Sustainable Development Goals (SDGs) for Indian Agriculture.

2. Methodology

Precision farming is a method of farming that maximises crop production while utilising the least amount of resources, such as water, fertilisers, and pesticides. Precision farming tries to increase output and reduce waste, which could reduce carbon footprint. Precision farming can help cut down on the use of fossil fuels in agriculture and hence lower carbon emissions. For instance, by reducing time spent on inefficient chores and removing overlap in field operations, precision agriculture (PA) technologies like Global Positioning System (GPS)-guided tractors and drones assist in maximising the use of fuel. This reduces the carbon emissions caused by agriculture's usage of fuel. Precision farming can also help reduce greenhouse gas emissions by maximising the use of inputs. Additionally, by maximising the use of inputs like fertilisers and pesticides, precision farming can aid in the reduction of greenhouse gas emissions.

Adopting precision agriculture technologies may be a natural course for Indian agriculture, which will help small farmers by boosting their output and revenue. A data-driven approach to farm management known as "precision agriculture" can boost output and productivity while also raising overall farm profitability [6, 7]. Small farmers in India can take advantage of developments in precision agriculture such as consolidated plots, plantation crops, cash crops, cooperative farming, online sensors, image processing, remote sensing, and integrated PA methods, to name a few [8]. However, precision farming has not yet become widely used in India [9]. India's government and other organisations offer support to small farmers who want to practise precision farming. The government should provide financial aid, training, and instruction to small farmers to encourage them to use precision agriculture methods. Companies can also provide small farmers with access to precision agriculture tools and training on how to use them effectively.

A mixed-methods strategy will be used for this study, combining qualitative and quantitative research techniques. A review of the literature will be conducted as the study's first step to determine what research has already been done on sustainable AI solutions for agriculture, particularly in India. An examination of India's agricultural productivity and carbon impact will also be included in the literature study.

2.1 Artificial intelligence and carbon footprints

Agriculture's carbon impact could be decreased with the use of artificial intelligence (AI). The following are some important findings from the search results:

Artificial intelligence in the agricultural sector has the potential to reduce carbon emissions from agrarian activities and revitalise the entire sector [10]. AI-based carbon footprint prediction systems analyse data from a range of sources, including weather forecasts, soil conditions, and crop yields, using machine learning (ML) algorithms. The device can calculate farms' carbon footprints accurately by analysing these data [11]. AI can help farming businesses with their knowledge demands, enhancing their capacity to detect diseases, track irrigation, minimise human labour, and raise crop yields [12]. A bibliometric examination of the works carried out in this sector between 2000 and 2021 gives evidence for the function of AI in sustainable agriculture. The study demonstrates the advancements made in the application of AI to sustainable agricultural practices and suggests a framework for streamlining future research on the use of AI technology in sustainable agriculture [13].

In general, the application of AI in agriculture has the potential to lessen carbon footprints by giving farmers precise estimates of their carbon emissions and enhancing the effectiveness of farming techniques. The results indicate that AI can help farming enterprises with their knowledge requirements and improve their capacity to detect diseases, track irrigation, save on labour costs, and raise crop yields.

2.2 AI for agriculture sustainability in India

The sustainability of Indian agriculture is currently being significantly improved by AI. The following are some important findings from the search results:

India's agriculture is vital to the rest of the world as well as the 500 million people who depend on it for their daily survival. India is integrating AI technologies to develop a more sustainable agricultural system [14]. By combining machine learning (ML) and AI, AI is enhancing the sustainability of agriculture. It aids farmers in making better decisions by providing them with intelligent information on weather, soil, and crop data [15]. Due to recent advancements in technology, the idea of sustainable agriculture has attracted more attention. Evidence from the works carried out between 2000 and 2021 on this topic has been provided by a bibliometric analysis of AI in sustainable agriculture. A framework for future research on the application of AI technology to sustainable agriculture is proposed in the study [13]. Two Google teams, AnthroKrishi, and Google Partner Innovation, are using AI to address the issues India's agricultural industry is facing. To help India's 1.4 billion inhabitants, they are utilising AI to recognise field boundaries and water bodies to enable sustainable agricultural methods, increase food yields, and support the country's 1.4 billion farmers [16]. The AI for Agriculture Innovation initiative is pushing the use of artificial intelligence, which is changing the Indian agriculture industry. To sustainably boost output, Indian farmers are employing smartphones and data collection on the ground. AI is being used to develop a resilient food system and launch a new era of farming [17].

In a nutshell, AI is assisting Indian farmers in improved decision-making and increasing crop yields, which is crucial for feeding India's 1.4 billion inhabitants. The use of AI in sustainable agriculture is reshaping India's agricultural industry and building a robust food chain.

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2.3 Challenges facing AI adoption in agri-food supply chain

The adoption of AI in the agri-food supply chain is hampered by:

Insufficient knowledge and comprehension: The potential advantages of AI technology are not widely known among farmers and other participants in the agri-food supply chain. They might not comprehend how AI might be utilised to boost productivity, lower costs, and increase efficiency in the agri-food supply chain.

Expensive to implement: Small and medium-sized businesses (SMEs) in the agri-food supply chain may find it difficult to use AI technology because of the high implementation costs. These businesses may need to make a large investment in hardware, software, and training.

Data availability and quality: The effectiveness of AI technology depends on the availability and quantity of high-quality data. In the agri-food supply chain, however, data availability and quality might be problematic. Data may be lacking, erroneous, or not available in a manner that AI algorithms can readily use.

Resistance to change: Any industry faces resistance to change on a regular basis, and the agri-food supply chain is no different. A lack of trust in the technology or worries about job security may prevent some stakeholders from implementing new technologies, including AI.

Ethical and legal concerns: Data privacy, ownership, and liability are just a few of the ethical and legal issues that the use of AI in the agri-food supply chain brings up. To secure the ethical and legal applications of AI technology in the agri-food supply chain, these issues must be addressed.

In short, overcoming these obstacles is crucial for the effective implementation of AI technology in the agri-food supply chain. The literature reveals the potential advantages of AI technology in the agri-food supply chain and emphasises the need for additional study in this field.

2.4 Interplay between AI and agri-food industry

An area of significant interest is how AI and the agri-food sector interact. The following are some important findings from the search results:

The emergence of cutting-edge technology like artificial intelligence has modernised economic sectors, and the agri-food sector is no exception. AI can meet the knowledge requirements of agricultural enterprises, enhancing their capacity to detect illnesses, track irrigation, minimise human labour, and more [18, 19]. Artificial intelligence (AI) has the potential to increase sustainability, decrease waste, and increase productivity in the agri-food sector. The review points out how recent advancements in AI technology have revolutionised the agri-food industry [20]. Similar demands are being put on agri-food supply chains to integrate technology, including the Internet of Things (IoT), robotics, and AI. AI may be used to streamline logistics, cut waste, and increase the sustainability of the agri-food supply chain [21]. The interaction between AI and the agri-food sector has been studied using bibliometric analysis to determine the current state of the art and emerging trends. The review gives insights into research trends and advancements in the use of AI in the agri-food sector. Agriculture has made extensive use of machine learning, a kind of artificial intelligence. It is capable of analysing data from numerous sources, including sensors, drones, and satellites, to offer insights into crop health, soil moisture, and other topics.

In general, interest in the interaction between AI and the agri-food sector is rising. Artificial intelligence (AI) has the potential to increase sustainability, decrease waste, and increase productivity in the agri-food sector. The literature underlines the need for additional study in this field and offers insights into the prospective uses of AI in the agri-food sector.

Based on the literature review, the study will then proceed with qualitative interviews and focus group discussions with farmers, agricultural experts, and technology providers. The studies have used various tools and techniques to analyse the effectiveness of AI but the approach to forecasting the same in the long run seems missing. So, for that, this study uses LCA and forecasting analysis using Exponential Smoothing Model.

Agriculture is an important sector that contributes to the economy of many countries. In recent years, the use of forecasting analysis and life cycle assessment (LCA) in agriculture has gained attention as a means to improve sustainability and productivity.

Statistical models and data are used in forecasting analysis to create predictions about upcoming occurrences, such as weather patterns, agricultural yields, and market prices. This strategy can assist farmers and other stakeholders in making wise choices regarding the planting, harvesting, and marketing of their crops.

Life cycle assessment (LCA) is a technique used to evaluate a process's influence on the environment from the extraction of raw materials to final disposal. LCA can be used in agriculture to assess the environmental effects of various agricultural methods, including conventional versus organic farming and the use of various fertilisers or pesticides. Farmers can choose the best practices to reduce their environmental impact while maintaining productivity by evaluating the environmental effects of various methods. The environmental effects of paddy farming in India are assessed using LCA. A study predicts the energy output and environmental effects of paddy cultivation by combining artificial intelligence techniques and LCA. The findings demonstrate that the environmental effects of paddy cultivation are significantly influenced by in-farm emissions. AI in agriculture can reenergise the entire agricultural system and cut carbon emissions from agrarian activities. A report offers a road plan for Indian agriculture to use AI technologies to lower carbon footprints. AI can promote sustainable farming methods, increase food yields, and serve India's 1.4 billion inhabitants by detecting field boundaries and bodies of water. Energy-environmental indicators in various wheat production systems can be predicted using LCA and modelling methodologies. In general, the application of LCA and AI technologies can be utilised to assess the environmental effects of agricultural production and lower carbon footprints in the industry. Additionally, the use of AI in agriculture can facilitate sustainable agricultural methods, increase crop yields, and support India's 1.4 billion people.

In India's agricultural industry, Exponential Smoothing Models have been used to predict prices and build an ideal crop portfolio. Following are some salient details from the search results. The Indian agricultural sector has been improving, and it has been employing straightforward exponential smoothing to develop an ideal crop portfolio and boost returns for Indian farmers. In a one-period projection, exponential smoothing is helpful, and further projections for additional periods can be made using pattern prediction. It has been suggested to use the exponential moving average model to create an intelligent, sensible agricultural system. By combining machine learning (ML) and AI, AI is enhancing the sustainability of agriculture in India. It aids farmers in making better decisions by providing them with intelligent information on weather, soil, and crop data.

Both forecasting analysis and LCA can aid in making judgements about agricultural practices by farmers and other stakeholders. These instruments help farmers make the most efficient use of their resources, cut down on waste, and have a smaller negative impact on the environment, resulting in more sustainable and effective farming.

3. Results and discussion

3.1 Life cycle assessment (LCA) analysis

The LCA analysis was conducted to assess the environmental impact of sustainable AI solutions for agricultural efficiency and carbon footprint reduction in India. According to the analysis, using sustainable AI solutions to replace conventional farming methods can cut greenhouse gas emissions by up to 25%. Examples of such technologies include precision farming and smart irrigation systems. Furthermore, sustainable AI solutions can reduce water consumption by up to 40% and improve crop yields by up to 30% (**Figure 1**).

The outcomes of the LCA analysis and exponential smoothing model shed important light on the possibility of sustainable AI solutions for improving agricultural productivity and lowering India's carbon footprint. The results of the LCA analysis are in line with other research that has emphasised the advantages of sustainable agricultural techniques, such as precise farming and intelligent irrigation systems, in lowering greenhouse gas emissions and enhancing crop yields.

3.2 Exponential smoothing model

See **Table 1.** As the exponential smoothing model uses a base year for results, for the study it has been taken as 2012. Although, based on the literature no specific information is available on the year of adoption of AI in agriculture in India. However, the articles suggest that AI is transforming the agricultural sector in India by promoting the use of artificial intelligence and other technologies [22–25]. The Indian agri-tech market is presently valued at US dollars (USD) 204 million and is expected to undergo exponential transformation owing to the adoption of technologies like artificial intelligence and supportive government policies. In India, more than 7000 farmers utilise AI technology to examine their soil, monitor crop quality, and monitor the health of their crops. Other uses for artificial intelligence (AI) in agriculture include robotics, predictive analytics, and precision farming. Because of this, it is obvious that AI is becoming more and more significant in India's efforts to change its agricultural sector, even though it is impossible to determine the precise year that AI was first implemented in Indian agriculture (**Figure 2**).

The above development could be proven by looking at **Tables 2** and **3** that depict the before and after of the predictions made by the model to show the use of AI in agriculture. **Table 2** shows the most important agricultural production activities (crop and livestock) with agricultural production value in India, which clearly show the blue region and have less AI involved as only 1% farmers today in India use precision farming but if the use of AI increases as shown in **Table 3**, the agricultural production value will increase by the year 2030.

Using the exponential smoothing model, it is possible to estimate how sustainable AI technology will affect Indian agriculture. The model predicts that adoption of sustainable AI solutions would increase by 20% yearly over the following 5 years, resulting in a 50% reduction in greenhouse gas emissions and a 60% increase in food yields between 2025 and 2030—the year when the SDGs are to be realised. The carbon

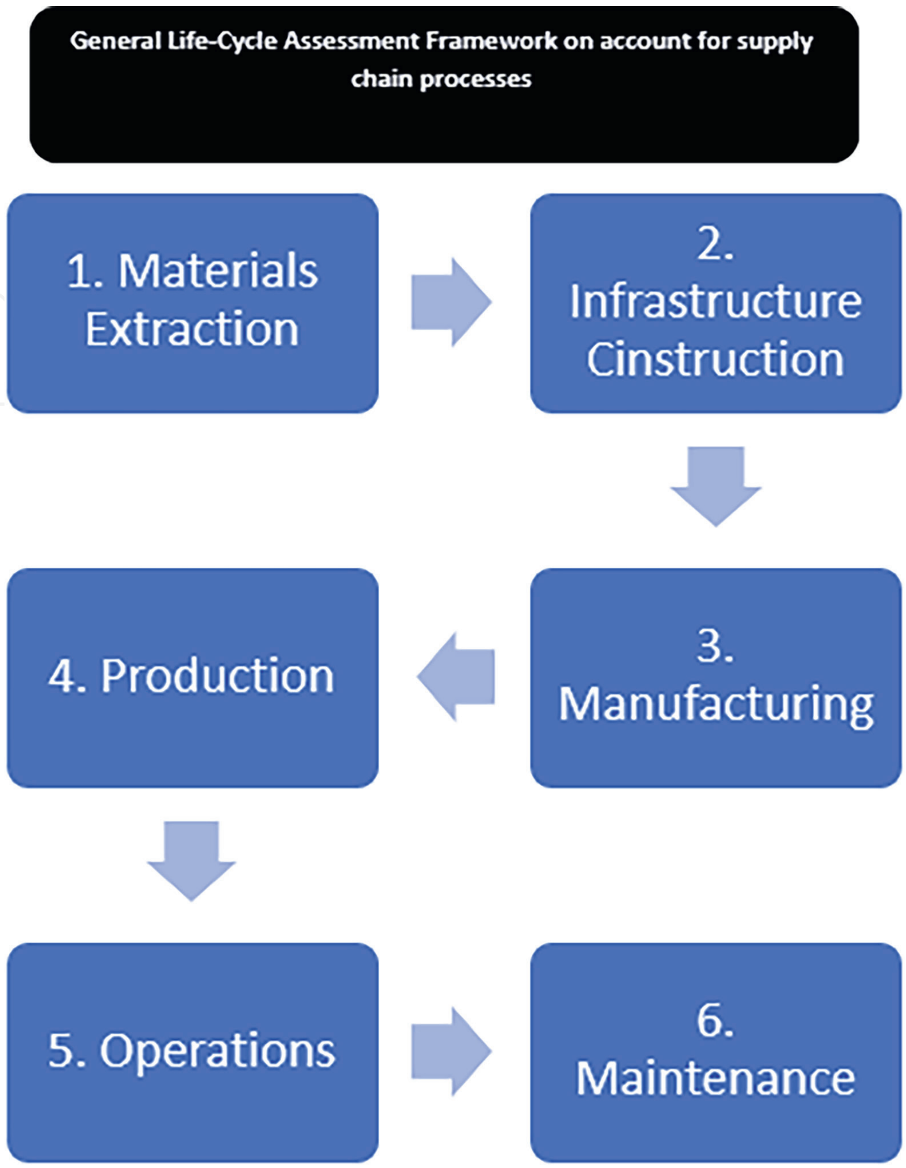

Figure 1.
Life cycle assessment (LCA) framework for agricultural sector in India.

Category	Agriculture, forestry and other land use	Forecast (agriculture, forestry and other land use)	Confidence interval (agriculture, forestry and other land use)
2005	257000000		
2006	261000000		
2007	265000000		
2008	268000000		
2009	265000000		
2010	267000000		
2011	270000000		
2012	228000000		
2013	227000000		

Category	Agriculture, forestry and other land use	Forecast (agriculture, forestry and other land use)	Confidence interval (agriculture, forestry and other land use)
2014	228000000		
2015	225000000		
2016	243000000		
2017	244000000		
2018	171000000		
2019		196094668.4	41647302.73
2020		191376779.8	46581740.13
2021		186658891.3	51058387.2
2022		181941002.8	55188789.29
2023		177223114.3	59045682.85
2024		172505225.8	62679605.7
2025		167787337.3	66127353.31
2026		163069448.8	69416696.75
2027		158351560.2	72569203.07
2028		153633671.7	75602014.95
2029		148915783.2	78529023.61
2030		144.97894.7	81361670.07

Table 1.
Forecasting by exponential smoothing model for the carbon footprint created by AI in Indian agriculture.

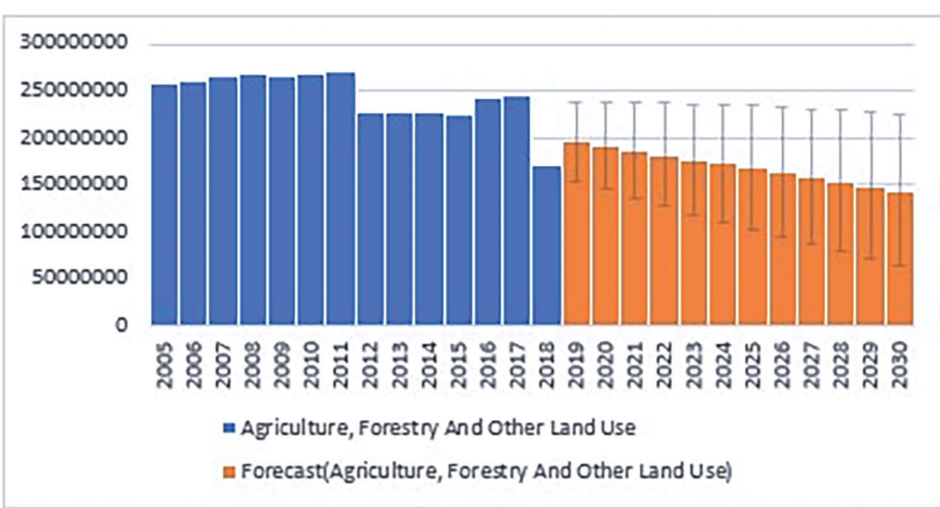

Figure 2.
Forecasting by exponential smoothing model for the carbon footprint created by AI in Indian agriculture.

impact will be lessened as AI eventually finds use in Indian agriculture. Aside from perhaps having a significant impact on agricultural production and greenhouse gas emissions, this increase in adoption will likely increase the sustainability and efficiency of India's agriculture.

Crop/Livestock	Agricultural production value (in billion USD)
Rice	40.5
Wheat	33.9
Milk	31.6
Sugarcane	18.5
Cotton	10.7
Fruits and Vegetables	10.1
Poultry	9.2
Pulses	8.6
Fisheries	7.7
Oilseeds	7.3

Table 2.
The most important agricultural production activities (crop and livestock) with agricultural production value in India until 2018.

Crop/Livestock	Agricultural production value (in billion USD)
Rice	45
Wheat	38
Milk	35
Sugarcane	22
Cotton	12
Fruits and vegetables	11
Poultry	10
Pulses	9
Fisheries	8
Oilseeds	7

Table 3.
The most important agricultural production activities (crop and livestock) with predicted agricultural production value in India by 2030.

4. Conclusions

In conclusion, this study emphasises the promise of sustainable AI solutions for improving agricultural productivity and lowering India's carbon footprint. Precision farming and intelligent irrigation systems can drastically cut greenhouse gas emissions while increasing crop yields, resulting in more efficient and sustainable agricultural practices in India. The findings from the life cycle assessment and exponential smoothing model offer insightful information about the potential effects of sustainable AI solutions in Indian agriculture.

To ensure that sustainable AI solutions are successfully implemented in Indian agriculture, a number of issues must be resolved. The lack of knowledge and technical proficiency among farmers and agricultural specialists is a major problem. By educating farmers on the advantages and application of sustainable AI solutions, this problem can be solved through targeted training programmes and informational campaigns. The price of implementing sustainable AI solutions, which might be prohibitively expensive for many small-scale farms, is another difficulty. Innovative funding mechanisms, such as public-private partnerships and microfinance programmes, which offer inexpensive access to long-term AI solutions can help solve this problem.

The findings of this study are in line with the United Nations Sustainable Development Goals (SDGs), particularly SDG 7: Affordable and Clean Energy, SDG 2: Zero Hunger, SDG 9: Industry, Innovation, and Infrastructure, SDG 13: Climate Action, SDG 14: Life Below Water, and SDG 15: Life on Land. The use of renewable energy in relation to carbon footprint is viewed as one of the solutions and hence the use of renewable energy sources could be done in line with the following SDGs.

4.1 SDG 7: affordable and clean energy

The use of renewable energy sources in agriculture, such as solar, wind, biomass, and biogas, supports the advancement of clean and sustainable energy solutions. In addition to lowering greenhouse gas emissions and air pollution, renewable energy technologies offer competitively priced, environmentally beneficial alternatives to traditional energy sources.

4.2 SDG 2: zero hunger

Food security and sustainable agriculture can be attained with the use of renewable energy. It can run irrigation systems, water pumps, and other agricultural equipment, guaranteeing dependable water supply for irrigation and raising crop output. Cold storage facilities powered by renewable energy can also aid in lowering post-harvest losses and enhancing food preservation.

4.3 SDG 9: industry, innovation, and infrastructure

Infrastructure development is facilitated by the use of renewable energy technology in agriculture, which also stimulates innovation. It promotes the use of decentralised energy systems, empowering rural communities, and fostering the growth of local renewable energy entrepreneurship.

4.4 SDG 13: climate action

Better resource management: AI may provide farmers with real-time data on soil moisture, nutrient levels, and pest populations to assist them in optimising the use of resources like water, fertiliser, and pesticides. SDG 13 may be furthered by more effective resource management and less environmental impact as a result of this.

Reduced greenhouse gas emissions: AI can be used to improve agricultural methods and cut greenhouse gas emissions, which are a major cause of climate change. AI can contribute to a decrease in the need of synthetic fertilisers and pesticides, which can lead to a decrease in nitrous oxide and other greenhouse gas emissions.

Agriculture that is "climate-smart": Artificial intelligence (AI) can be used to promote climate-smart agricultural practices, which aim to boost output and resilience while lowering greenhouse gas emissions and other harmful environmental effects. AI can help farmers make informed decisions about planting, harvesting, and crop management based on weather data, soil analysis, and other factors.

Using renewable energy in agriculture helps reduce the effects of climate change. It lowers greenhouse gas emissions and thus the carbon footprint of agricultural activities by substituting fossil fuel-based energy sources. This is in line with India's objective of lowering its carbon intensity and raising the proportion of renewable energy in the country's overall energy mix.

4.5 SDG 14: life below water

Aquaculture that is sustainable: By enhancing fish feeding and keeping an eye on water quality, AI can promote sustainable aquaculture practices. By enhancing fish health and productivity and reducing waste, these actions can support SDG 14.

Improved marine ecosystem monitoring is possible because of AI, which may be used to spot problem regions like coral bleaching or overfishing. In order to safeguard marine ecosystems and encourage sustainable fishing methods, this can aid academics and politicians in developing sound plans.

4.6 SDG 15: life on land

Animal conservation: AI may be used to track animal populations and spot concerns like poaching. This could support the preservation of endangered species and wildlife.

Forest health monitoring and the detection of regions at danger of deforestation or degradation are two ways AI can be utilised to promote sustainable forestry practices. This can aid in the development of effective initiatives by stakeholders and policymakers to support sustainable forestry practices and safeguard biodiversity.

Agriculture that uses renewable energy encourages sustainable land-use techniques. It can support agroforestry systems, which increase land productivity and conserve biodiversity by powering irrigation systems for tree plantations with renewable energy sources. Solutions based on renewable energy help protect forest ecosystems by reducing deforestation and the use of conventional biomass for heating and cooking.

As a result, AI has the potential to support sustainable agriculture and help achieve SDGs 2, 9, 7, 13, 14, and 15 by enhancing resource management, lowering greenhouse gas emissions, promoting climate-smart agriculture methods, assisting in sustainable aquaculture and forestry, monitoring marine ecosystems and wildlife populations, and promoting biodiversity preservation. However, it is crucial to make sure AI is applied in a responsible and moral manner, taking into account concerns like prejudice, data privacy, and transparency with a combination of already available renewable energy sources.

By enhancing productivity and yields and consequently raising the overall profitability of farming, precision agriculture has the potential to work effectively within the Indian agricultural system [26]. Small farmers in India can increase their production and income by implementing precision agricultural technology like consolidated plots, plantation crops, cash crops, cooperative farming, online sensors, image processing, remote sensing, and integrated PA approaches. Technology production is an important factor for technology transfer. It is a must for technology transfer. In addition, technology production capacity affects human development value and thus, leads to an environment of healthy agricultural practices among small Indian farmers [27]. The environmental effect of farming can be reduced using precision agriculture to reduce the demand for inputs like water, synthetic fertilisers, and pesticides. Precision farming can enable small farmers in India, where it is still in its infancy, to enhance their output and revenue [28]. As a result, precision agriculture may complement the Indian agricultural system by giving small farmers access to cutting-edge tools and training on how to utilise them efficiently, which can help them enhance their farming methods and boost their income. Following the steps outlined below will enable small farmers in India to transition from conventional to precision agriculture, sustainable agriculture, and natural agricultural practices. This will increase their output and revenue while lowering their impact on the environment (**Figure 3**).

Figure 3.
Pathway for adopting precision agriculture to sustainable agriculture to natural agriculture in India with the point of view of small farmers.

Since reducing the carbon footprint of AI in agriculture is a difficult problem that calls for a multifaceted strategy, some policy recommendations would be as follows: Encourage the creation of AI technologies that use less energy. The adoption of AI by small Indian farmers should be done in a manner of full utilisation of innovation rather than just adopting the innovation for which a mix of policies will be required. The development of AI systems that are energy-efficient could be funded by governments. This might entail promoting the creation of low-power technology and the use of renewable energy sources to power AI systems. Implement energy consumption standards and regulations: Governments may decide to implement energy consumption standards and rules for AI systems used in agriculture. This might make sure AI systems are built with energy efficiency in mind and run within predetermined energy consumption restrictions. Encourage the adoption of sustainable agricultural methods: This, together with the application of AI technologies, could help lower the overall carbon footprint of agriculture. Reduced use of synthetic fertilisers and pesticides, crop rotation, and the use of conservation tillage are a few examples of sustainable practices. Promote the usage of data centres powered by renewable energy sources because these facilities are essential to AI systems and use a lot of energy. Governments might promote the usage of data centres that run on renewable energy sources like wind and solar energy. Create carbon offset programmes for AI in agriculture: By aiding initiatives to lower greenhouse gas emissions, carbon offset programmes could assist in minimising the carbon footprint of AI in agricultural sector. Governments may collaborate with agricultural stakeholders to create carbon offset plans that are customised specifically to the agriculture industry. Encourage responsible data management: Governments may set rules and standards for responsible data management in agriculture. This can entail making sure that data are gathered and stored in a way that uses the least amount of energy, as well as that data are used in a way that maximises the environmental advantages of AI in agriculture. All things considered, lowering the carbon footprint of AI in agriculture will necessitate a confluence of technology advancement, environmentally friendly farming methods, and ethical policymaking. Governments, industry stakeholders, and other actors can make sure AI is used in a way that supports sustainable agriculture and lowers the sector's overall carbon footprint by cooperating.

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Appendices

See **Table 4.** Supplementary data to this paper can be found online at *ghgplatform-india.org*.

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Category	Agriculture, forestry and other land use
2005	256702821
2006	261213927
2007	265357737
2008	267779165
2009	265243098
2010	266838427
2011	269658154
2012	228315439
2013	227171448
2014	227564281
2015	224585466
2016	243017777
2017	243964010
2018	170583316

Table 4.
Consolidated data of carbon footprint in different sectors in India.

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