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AI in Environmental Sustainability: A Review of Applications and Challenges

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Abstract: The paper explores the major effects of Artificial Intelligence (AI) in promoting sustainable development in Indian context. It covers its expanding impact in important sectors such as agriculture healthcare, renewable energy resources, education, waste recycling, and mitigation of global warming. Smart energy forecasting precision farming and computerized recycling are among the AI-powered solutions being used in India to address significant socioeconomic and ecological issues. Environmental impacts, which include electronic waste excessive energy consumption and harmful effects by rare earth processing, with challenges such as confidentiality of data the digital gap, and limited legal frameworks, pose significant challenges to inclusive AI adoption. The evaluation underlines India's pressing requirement to implement energy-efficient AI to build green infrastructure, ensure ethical adoption, and strengthens regulatory systems. Artificial Intelligence (AI) has enormous potential to generate long-term and fair prosperity in India if the government, private sector, and academics work together.

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1. Introduction

Environmental sustainability entails meeting current needs without compromising the capacity of future generations to meet their own needs. Natural resources management, environmental degradation mitigation, pollution reduction, and green jobs included in sustainability. Most importantly, it indicates our ethical responsibility and duty to conserve the environment (United Nations, 2023). Examples of Artificial intelligence are Reasoning that is logical conclusions, acquiring and using information as Learning and self-correction . Artificial intelligence AI is the imitation of human intelligence by technology, specifically computer systems Artificial intelligence (AI) is being crucial in furthering sustainability by giving novel solutions to different environmental, social, and economic concerns AI is improving resource efficiency, waste reduction, and enhances climate action by using intelligent data analysis, automation and predictive modeling. Key applications include optimizing energy usage in smart networks, increasing agricultural production through precision farming, providing real-time environmental monitoring, and promoting circular economy practices. Subfields such as Machine Learning and Natural Language Processing enable AI systems to examine massive datasets and facilitate decisions based on evidence towards sustainable development. As AI advances, it has the potential to accelerate global efforts to build a more resilient and environmentally friendly future (Russell &Norvig, 2021; United Nations, 2023).

2. Materials and methods

This research includes a qualitative research methodology to analyse the application of Artificial Intelligence (AI) in enhancing sustainability in Indian context. The study is carried out by secondary data analysis, that focus on identifying AI technologies that are being incorporated into sustainable approaches across area such as agriculture, waste management, energy, and environmental conservation in India.

In the study, data was collected from a wide range of Indian sources to ensure contextual accuracy as well as depth. Databases are used to collect academic literature, such as INFLIBNET Shodhganga, J-Gate, and Google Scholar, emphasising peer-reviewed research on AI applications in sustainable development in India (Shodhganga, 2024; INFLIBNET, 2024). Important government documents and papers were consulted, with National Strategy for Artificial Intelligence (NITI Aayog, 2018), reports are also collected from the Ministry of Electronics and Information Technology (MeitY, 2023), Ministry of Environment, Forest and Climate Change (MoEFCC, 2022), Indian Council of Agricultural Research (ICAR, 2022), and Central Pollution Control Board (CPCB, 2023). Examples of successful projects, such as Microsoft's AI-based seed app in Andhra Pradesh (Rajiv & Prasad, 2021), the pilot on waste management in Pune and Indore (Deshmukh&Nair, 2021), and the renewable energy model developed by IISc and various IITs (Chatterjee et al., 2022), have been used as examples of real-world implementation. Indian think tanks and NGOs, including the Energy and Resources Institute (TERI, 2023), the Centre for Science and the Environment (CSE, 2023) and the India AI Platform (India AI, 2024), provide comprehensive data on AI policy, adoption challenges and deployment at grass-root level, which are the additional insights that were provided.

3. Results

The research shows that Artificial Intelligence (AI) is constantly being integrated into many sustainability initiatives across India, its application remains unbalanced and often limited to key projects or urban-centric implementations.

1. Artificial Intelligence in Indian agriculture is enhancing crop productivity by optimizing resource use with environmentally sustainable practices. As India faces challenges such as water shortage, climate change, soil degradation, and over-fertilisation, artificial intelligence-driven have become essential for resilient and precision farming. In desert states like Rajasthan and Gujarat, AI-powered irrigation technology use real-time data from soil moisture sensors and weather forecasts that identify optimal watering schedules, and help water conservation also improve crop health (Patel & Yadav, 2022). Fertilizers application has also been revolutionized with artificial intelligence tools that recommends precise nutrient doses based on soil requirement, as adopted in ICAR and Krishi Vigyan Kendra projects in Haryana and Punjab, reducing both costs and environmental harm (Sharma et al., 2023). AI-enabled computer vision and sensor-based tools like rice, cotton, and wheat in Maharashtra and Telangana develop pest management, which enabled farmers to take scheduled and targeted action (Gupta et al., 2021). AI-powered imaging systems and drones in Madhya Pradesh and Karnataka are being used to assess soil health, and also Digital India initiatives in Uttar Pradesh and Bihar, where AI algorithms are being integrated for early detection of plant diseases and nutrient deficiencies (Singh & Bansal, 2023; Kumar et al., 2022). These examples demonstrate how AI is empowering Indian farmers with data-driven decision-making tools to achieve sustainable agriculture.

Table 1: AI Applications in Indian Agriculture

	States / Projects INDIA	**Field of application**	**AI Technology**	**Impact**
1	Gujarat Rajasthan,	Management of Irrigation	AI models based on Soil sensors and weather	less water use , crop health improvement
2	Haryana Punjab, (ICAR, KVK)	Fertilizer	AI-based soil analysis and dosage advice	input costs lowered, soil pollution reduction
3	Maharashtra, Telangana	Pest Control	real-time detection Computer vision,	Reduced pesticide usage, minimized crop loss
4	Karnataka Madhya Pradesh	Monitoring of Soil Quality	Drones with multispectral imaging	land use improvement and soil treatment
5	Bihar (Digital India projects), Uttar Pradesh	Management of Plant Health	AI-analyzed drone/satellite imagery	Early disease detection, better yield and resource use

2. Energy and waste management: Artificial Intelligence (AI) is playing an important role in promoting sustainability agenda of India in the areas of renewable energy and waste management., AI supports real-time forecasting of energy demand based on weather, historical usage, and grid flow data, significantly aiding utilities like Tata Power and agencies such as POSOCO by enabling smart grid infrastructure (Sharma & Gupta, 2022; Singh et al., 2021).in research institutions like IITs and the Central Electricity Authority significant contribution have been made for AI .these institute facilitates the integration of renewable sources by predicting generation trends and the highest storage technology (Patel & Raj, 2023; Nair &Bansal, 2020). In Tamil Nadu and Gujarat, Artificial Intelligence is being used to integrate turbine

blades for optimal rotation speed and to improve efficiency, while predictive maintenance systems reduce operational risks and unplanned downtime (Gupta & Sharma, 2021; Bansal &Yadav, 2022). Likewise, AI technology in which drone is using now widely adopted in solar parks to detect faults and predict solar energy yield based on environmental data (Singh et al., 2022; Raj & Patel, 2021).

Beyond energy, AI innovations are transforming waste management in India's urban centers. AI-powered robotic systems are being piloted in cities like Bengaluru and Delhi to sort waste automatically using computer vision, while smart waste bins with embedded sensors are already operational under Smart City projects (Choudhary & Sharma, 2023; Singh & Gupta, 2022). AI tools are also helping e-commerce and retail sectors optimize logistics and inventory, reducing surplus and preventing product waste (Kumar &Verma, 2021). Lastly, AI-enabled food redistribution platforms in cities such as Mumbai and Delhi ensure leftover food from restaurants is sold or donated efficiently, minimizing edible waste and enhancing food equity (Mehta &Choudhary, 2023). These initiatives highlight AI's growing influence in shaping a more resilient and sustainable India.

Table 2: Applications of AI in Renewable Energy and Waste Management in India

Renewable Energy		
Application	**Details & Examples**	**Impact**
Smart Grids & Forecasting	Tata Power, IITs, POSOCO using AI for demand prediction via weather and grid data	Load balancing, reduced outages Sharma & Gupta (2022); Singh et al. (2021)
Renewable Energy Integration	AI-based forecasting and battery optimization by CEA, IITs	Clean energy grid integration Patel & Raj (2023); Nair &Bansal (2020)
Wind Turbine Optimization	Real-time blade angle control in Gujarat, Tamil Nadu	Efficiency during wind variability Gupta & Sharma (2021)
Predictive Maintenance	Sensors tracking temperature, vibration anomalies in turbines	Reduced breakdowns and downtime Bansal&Yadav (2022)
Solar Fault Detection	Drone-based AI scanning for defects in Rajasthan, MP, Telangana	Reduced energy loss, timely cleaning Singh et al. (2022)
Performance Forecasting	AI uses temperature, radiation, and cloud data to estimate output	Efficiency in cloudy or non-optimal conditions
Waste Management		
Application	**Details & Examples**	**Impact**
Robots AI-Powered	for automatic waste segregation Pilots in Delhi and Bengaluru	Accurate material sorting Choudhary& Sharma (2023)
Smart Waste Bins	auto-sorting and alert systems Deployed in Pune, Hyderabad, Chandigarh with	Better pickup scheduling, reduced overflow Singh & Gupta (2022)
Optimization of Supply Chain	AI in Indian retail for predicting demand in FMCG and food sectors	Minimization of overstock and waste Kumar &Verma (2021)
Platforms for Food Waste	Apps in Mumbai, Delhi matching excess food supply with real-time demand	Reduced edible food waste, food equity Mehta &Choudhary (2023)

3. AI in Environmental Monitoring and Climate Mitigation

Climate change and the degradation of the environment present challenge to India's public health biodiversity and sustainable development objectives. With its ability to facilitate automated data collecting, real-time analysis, predictive modelling, and well-informed decision-making across industries, artificial intelligence (AI) is becoming more widely acknowledged as a game-changing tool in tackling these issues. The Central Pollution Control Board (CPCB) and state pollution are leading projects to monitor air and water quality in real-time with help of AI. Sensor networks are used by these systems and to forecast pollution levels, supporting quicker interventions (CPCB, 2024). India is using AI to monitor endangered species such as tigers and elephants in wildlife conservation. To detect species and identify risk, the WILD-AI system utilize, machine learning by drones and camera traps data. To aid in early interventions and decrease casualties, the Wildlife Conservation Trust in Maharashtra maps human-wildlife conflict zones using predictive models (Patel et al., 2025; Wildlife Conservation Trust, 2023). The National Natural Resources Management System (NNRMS), collaborated with ISRO, make use of AI-integrated satellite data to monitor illicit logging in states such as Madhya Pradesh and the Northeast for deforestation. Platforms such as Omdena and UP42 assist in spatial analysis and alert generation to support forest department operations (Omdena, 2024; UP42, 2023).India's coral reefs, specifically in the Gulf of Mannar ,Lakshadweep, and the Andaman & Nicobar Islands, are analysed using AI-enabled autonomous underwater vehicles (AUVs). the National Institute of Ocean Technology (NIOT) developed the tool, collect imagery and use machine learning to detect coral bleaching and assess reef health for conservation planning (India Today, 2025; IRJMETS, 2025).

4. Climate Change Mitigation

AI is also a significant tool in India for the response to climate change. AI-powered models to improve weather forecasts and predict extreme climate events such as floods, droughts, heatwaves, and cyclones are employed by the India Meteorological Department (IMD), in collaboration with IITs and IISc, These modals are crucial for disaster preparedness in vulnerable states such as Bihar, Assam, Rajasthan, and Odisha (Sharma, 2023; Verma& Reddy, 2022).Industries are constantly including AI for emissions reduction through energy-efficient infrastructure, smart grid technologies, and process optimization. Bengaluru and Mumbai cities are applying AI-based energy monitoring tools aligned with national goals under the National Action Plan on Climate Change (NAPCC) (Nair, 2021; Patel & Kumar, 2020; Bansal et al., 2021). Also, to enhance carbon capture and storage (CCS) systems in thermal power plants as well as in research facilities AI is being used. Machine learning helps to identify optimal CO_2 absorption conditions and evaluate material performance. Institutions like TERI, IIT Delhi are leading in these innovations (Singh et al., 2022; Patel & Raj, 2023; Gupta, 2021).

5. Policy Support and Implementation Gaps

To develop AI policy India has made significant strides through the "National Strategy for Artificial Intelligence" (2018) by NITI Aayog, which detect AI as a tool for inclusive growth and sustainability. The strategy outlines focus areas such as agriculture, healthcare, education, smart mobility, and environmental protection. In addition to various Indian states such as Tamil Nadu, Telangana, and Maharashtra have launched their own digital AI missions aimed at leveraging AI for development and governance .However, despite these important policy framework, the implementation at the grassroots level remains limited due to challenges such as insufficient digital infrastructure in rural states, lack of AI-skilled human resources, insufficient funding for pilot programs, and less awareness among local administration. Therefore, bridging the policy-to-practice gap is essential for ensuring that AI-driven sustainability goals reach marginalized and less resourced regions of India

6. Challenges of AI in Sustainable Development

AI has the potential to help India achieve its sustainability goals, but several challenges stand in the way of a responsible and equitable adoption. Training AI models uses a lot of energy, especially in data centers that rely on coal, which adds to India's carbon emissions (Sharma & Gupta, 2022). The fast pace of AI hardware upgrades also increases the country's e-waste, and there is not enough infrastructure for safe recycling (Verma et al., 2023). The global supply chain for AI depends on mining minerals in ways that harm the environment and raise ethical questions (Kumar & Mehta, 2022). Deep learning and large language models use even more energy, following global patterns but creating special risks in India, where coal is a main energy source (Strubell et al., 2019; Narayan & Choudhary, 2022). Some global tech companies in India are starting to use greener data solutions, but most local data centers still use regular electricity and need large amounts of water for cooling (Yadav & Gupta, 2023). In addition to these environmental issues, there are also challenges such as low digital literacy and limited access to AI in rural areas, which hinder everyone's ability to benefit. For AI to truly support sustainable development, India needs to tackle both digital inequality and the environmental impact of AI systems.

Table 3: AI in India Environmental and Infrastructural Challenges

References	Challenge	Description	Examples / Impacts
Sharma & Gupta (2022); Singh &Yadav (2021)	High Energy Consumption	AI model training consumes massive electricity, mostly from coal-based grids	Data centers in Bengaluru & Hyderabad significantly contribute to India's emissions
Verma et al. (2023)	E-Waste Generation	Rapid hardware obsolescence from AI tech increases electronic waste	India ranks 3rd globally in e-waste; unsafe informal recycling causes toxic exposure
Kumar & Mehta (2022); Kumar &Yadav (2021)	Resource Exploitation	AI hardware depends on rare minerals (lithium, cobalt) extracted via unsustainable practices	Environmental degradation and unethical mining linked to AI supply chains
Strubell et al. (2019); Narayan &Choudhary (2022)	Energy-Intensive Model Training	Deep learning and LLM training consumes energy equal to many homes' yearly use	Training GPT-3-type models strains Indian power infrastructure
Yadav& Gupta (2023)	Data Center Sustainability	Most Indian data centers rely on non-renewable power and consume large volumes of water	Growing clusters in Maharashtra and Tamil Nadu risk overstressing local grids and water sources
General analysis; implied policy context	Infrastructure and Digital Divide	Rural areas lack connectivity and digital literacy for equitable AI adoption	Limits AI's reach in agriculture, health, and education sectors

General concern in Indian AI discourse	Data Privacy and Ethics	Lack of strong data protection laws and AI governance	Raises risks in public sector AI deployment and surveillance

Figure 1: At a small family farm near Bengaluru, India, the farmers now uses AI for predictive modelling and tailored advice Times of India. (2024, May 8).

Figure 2: AI technology is being used to monitor wildlife activity in reserves like Pench Tiger Reserve, enhancing conservation efforts and species protection (Times of India, 2024).

Figure 3: An AI-powered QR code system helps Indian waste pickers track and manage recyclables more efficiently International Telecommunication Union. (n.d.).

4. Discussion

The study displayed Artificial Intelligence is being used more often in different sustainability sectors in India, and it is making a real difference. AI-Sowing App of Microsoft with, ICRISAT, in agriculture, has helped farmers increase crop yields by up to 30% in Andhra Pradesh (Rai & Prasad, 2021). By solar forecasting in renewable energy AI tools have enhanced and helped the power grid stable in Rajasthan and Gujarat (Chatterjee et al., 2022). "Swachhata-Mitra" AI-powered models in Indore have made efficient waste collection and also improved waste sorting (Deshmukh & Nair, 2021). The Wildlife Institute of India has also used AI camera traps to monitor tiger reserves in real time, which has helped improve conservation strategies with better data analysis (WII Report, 2022).

Even with these positive results, using AI is not the same everywhere in India because of differences in infrastructure, education, and the economy. There are not enough AI training programs at the local level, and funding for local AI research is limited. Data governance is also a concern. As more AI systems are built, it is important to consider the environmental impact of large data centres and how to handle e-waste responsibly. Better coordination between institutions and more public-private partnerships are needed to make AI a regular part of India's sustainable development (Mitra & Roy, 2023). With the right support and ethical use, AI could play a key role in India's move toward sustainability.

5. Conclusion

Artificial Intelligence offers real hope for tackling major environmental issues, such as climate change, renewable energy, sustainable farming, and waste management. With its ability to provide data-driven insights, make predictions, and automate processes, AI is already helping us move toward a more sustainable future. Still, this progress comes with environmental challenges. Running AI models uses a lot of energy, creates electronic waste, and depends on rare earth materials, all of which raise concerns about its impact on the planet. To make the most of AI's potential; we need to balance innovation with responsibility. This means improving energy efficiency, using renewable power, managing e-waste carefully, and choosing sustainable hardware. Working together across industries, universities, and governments, and setting clear rules, will help AI grow in ways that benefit both people and the environment.

As we move forward, our goal should be clear: develop AI that not only addresses sustainability challenges but is also sustainable itself. By including environmentally friendly practices at every stage of AI's development, we can make sure that technology and nature advance together.

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