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Green Intelligence: Transforming Environmental Science through Artificial Intelligence

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Abstract
Artificial Intelligence (AI) has emerged as a transformative force across scientific disciplines, with profound implications for environmental science. In this paper, let us explore the multifaceted impact of AI technologies including machine learning, deep learning, computer vision and natural language processing on environmental monitoring, modelling, prediction and policy formulation. AI enhances data processing from satellites, sensors and citizen science platforms, improves the accuracy of climate and ecological forecasts and enables real-time decision-making for conservation and sustainability. Case studies in wildfire prediction, deforestation tracking, and species identification illustrate the practical utility of AI. Integration of AI into environmental science promises more responsive, scalable and equitable environmental governance. This editorial underscores the necessity of interdisciplinary collaboration to maximize the potential of AI while mitigating its ecological and ethical risks.

Keywords: Artificial Intelligence; Environmental Science; Machine Learning; Remote Sensing; Climate Modelling; Biodiversity Monitoring; Sustainable Development

Introduction
Environmental science faces unprecedented challenges in the Anthropocene, from accelerating climate change and biodiversity loss to pollution and land degradation. Traditional methodologies often struggle to process the volume, velocity and variety of environmental data generated by satellites, IoT sensors, drones and social platforms. Artificial Intelligence (AI), a suite of computational techniques capable of identifying complex patterns, making predictions and automating decisions from massive datasets, has rapidly transitioned from a small tool to a central pillar in environmental research and management. Recent applications of AI in environmental sciences have surged, particularly since the emergence of deep learning algorithms. Over 65% of environmental tasks utilizing AI tools initially relied on conventional statistical models. AI enhances data analysis efficiency, supporting projects focused on environmental and sustainable goals, as seen in the European Union's supercomputing ecosystem program.

Many recent studies have highlighted the use of AI in different aspects of environmental sciences (Vartziotis et al., 2025; Alotaibi and Nassif, 2024; Ramachandra, 2025; Russo and Ciaccio, 2023; Ebtehaj, 2024; Kathua et al., 2025; Mandal et al., 2025). Konya and Nematzadeh (2023) highlighted that over 65% of environmental tasks initially relied on conventional statistical and mathematical models before adopting AI tools, which can now efficiently analyze and process large datasets. Collaboration between environmental and AI professionals is crucial to fully leverage the potential of AI in addressing pressing environmental challenges, highlighting the importance of interdisciplinary cooperation in this domain. However, concerns about energy consumption and carbon emissions from AI model training highlight the need for sustainable AI technology and collaboration between environmental and AI professionals. Let us examine how AI is reshaping environmental science across key domains of environmental studies.

AI-enhanced environmental data acquisition and processing
Research on artificial intelligence in environmental data acquisition and processing has emerged as a critical area of inquiry due to escalating environmental challenges such as climate change,

pollution and biodiversity loss, which demand timely and accurate monitoring solutions (Ahmad et al., 2025; Leong, 2025). The practical significance is underscored by the need for sustainable resource management and improved ecological decision-making. Modern environmental monitoring relies heavily on remote sensing, in-situ sensors and citizen science platforms. AI algorithms, particularly convolutional neural networks and recurrent neural networks, excel at processing this heterogeneous data. For instance, deep learning models can automatically segment land cover from high-resolution satellite imagery with high accuracy. Similarly, AI-driven data fusion techniques integrate satellite, drone and ground sensor data to produce comprehensive environmental indicators. Natural language processing tools also extract insights from unstructured sources like scientific literature or social media during environmental disasters, enabling faster situational awareness and response. AI in environmental data acquisition and processing addresses the challenges in timely, accurate and scalable environmental monitoring amid escalating ecological threats.

Predictive modelling and forecasting

AI surpasses the traditional statistical models in capturing nonlinear data in environmental systems. Recent applications of AI in environmental sciences include the use of Vision Transformer models for identifying and classifying environmental features, enhancing data quality and visualizing environmental impacts (Russo and Ciaccio, 2023). Vision Transformer models are highlighted for their proficiency in identifying and classifying environmental features while Diffusion models are noted for their capability to generate realistic images. These generated images can be utilized for visualizing environmental impacts and creating synthetic images for training datasets, thereby improving the data quality and communication in environmental research. In hydrology, specialized neural networks predict river discharge and flood events with greater lead time and precision than physical models alone. In air quality forecasting, hybrid AI-physics models (Fig. 1) now provide city-scale pollution predictions days in advance. Moreover, AI enables "nowcasting" real-time prediction of environmental phenomena such as algal blooms or wildfire spread critical for emergency response and resource allocation.

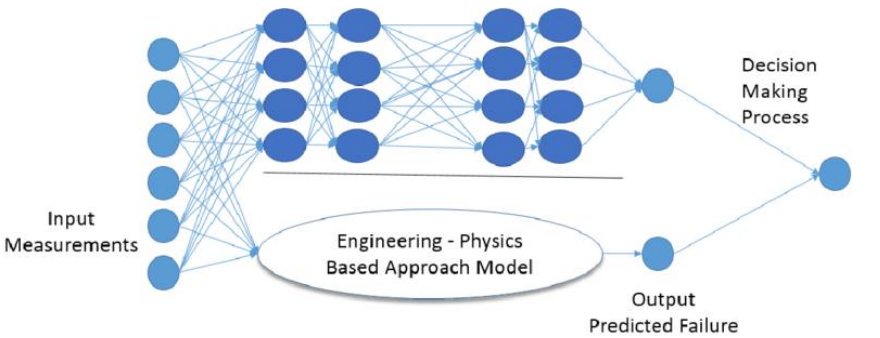

Fig. 1. Artificial Intelligence combined with Physics Model for real-time decision making (Muthu et al., 2018)

Biodiversity and Ecosystem Monitoring

AI has emerged as a pivotal tool in biodiversity and ecosystem monitoring, offering innovative solutions to address the pressing challenges posed by habitat destruction, climate change and human activities. By using advanced technologies such as machine learning, deep learning and predictive analytics, AI enhances the ability to monitor ecosystems and manage biodiversity effectively. The following sections outline key applications and benefits of AI in this field. AI algorithms analyze camera trap footage and GPS data to monitor wildlife populations, improving anti-poaching efforts and species protection. AI-powered image analysis aids in assessing forest health, detecting deforestation and identifying restoration needs. Techniques such as acoustic monitoring and environmental DNA analysis enable the identification of various species, including the endangered ones (Chisom et al., 2024). AI also facilitates species distribution modelling and disease prediction, allowing for proactive rather than reactive conservation strategies (Bhakhar et al., 2025).

AI is revolutionizing conservation biology. Automated species identification via image and audio recognition democratizes biodiversity data collection, allowing scientists and researchers alike to contribute to global databases. Deep learning models analyze camera trap images to estimate animal populations and detect illegal activities such as poaching. In marine environments, AI classifies coral reef health from underwater video with expert-level accuracy. Such tools significantly scale monitoring efforts, particularly in remote or under-resourced regions. Promising opportunities are presented for applying AI in the Earth and environmental sciences, emphasizing the need for effective use of massive volumes of environmental data from satellite and in-situ sources to enhance numerical weather prediction (NWP) and other related applications (Boukabara et al., 2021).

Climate science and earth system modelling

Climate models are becoming increasingly AI-augmented. Recent applications have been documented of AI in climate science, focusing on key areas including extreme weather prediction and nowcasting, carbon emissions tracking and estimation, climate change adaptation and mitigation planning, climate model emulation and climate-related decision support systems (Ramachandra, 2025). Emulators trained on complex general circulation models can simulate climate scenarios faster, enabling rapid testing and policy evaluation. AI also contributes to carbon accounting by estimating emissions from satellite-observed infrastructure using computer vision. Furthermore, reinforcement learning techniques are being used to optimize renewable energy grids and design efficient carbon capture strategies, aligning AI directly with climate mitigation goals. It is estimated that scaling AI applications could potentially reduce global greenhouse gas emissions by 5–10% by 2030. Thus, AI and machine learning can significantly enhance climate science by analyzing large datasets, improving forecasts and optimizing climate solutions.

Policy, ethics and challenges

The integration of AI into environmental sciences presents a great opportunity to enhance sustainability efforts, yet it also raises significant ethical and policy challenges. AI can optimize resource management, improve environmental monitoring and support policy development. The use of AI raises concerns about data privacy and the potential for biased algorithms, which can lead to inaccurate predictions and public health risks (Akhshik and Akhshik, 2025). "Black-box" models may lack transparency, making it difficult for stakeholders to trust or interpret results. Additionally, the computational energy demands of large AI models can contradict sustainability objectives. The energy consumption associated with large-scale AI models poses environmental concerns that must be managed (Tariq, 2025). To address these issues, the field is moving toward explainable AI, privacy-preserving techniques like federated learning and "Green AI" principles that emphasize energy efficiency and hardware optimization.

Conclusion

AI is a powerful amplifier of human capability in environmental science. It enhances human expertise rather than replacing it, showcasing the synergy between AI and human skills for innovative problem-solving in complex environmental and agricultural challenges. Future work must prioritize inclusive co-design of AI tools with local communities and Indigenous knowledge holders, development of open and interoperable environmental AI platforms, and integration of AI literacy into environmental science education. As climate urgency intensifies, the combination of AI and environmental science will be pivotal in building a resilient, data-driven and just planetary future. Responsible development requires political decision-makers, researchers and industry leaders to establish ethical guidelines and transparency protocols.

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