

Feasibility of Artificial Intelligence in the Enforcement of International Environmental Law

1. Mostafa Yousofi Majd[✉]: Department of Law, Ha.C., Islamic Azad University, Hamedan, Iran

2. Meisam Norouzi^{✉*}: Assistant Professor, Department of Public International Law, Faculty of Humanities, Bu-Ali Sina University, Hamedan, Iran

3. Sobhan Tayebi[✉]: Department of Law, ST.C., Islamic Azad University, Tehran, Iran

*Correspondence: m.norouzi@basu.ac.ir

Abstract

This study examines the feasibility of artificial intelligence (AI) in the enforcement of international environmental law. Considering that the ultimate objective of international environmental regulations is their effective implementation, the United Nations Environment Programme reported in January 2019 that the enforcement of these laws has been weak and unsuccessful (UNEP, 2019). Therefore, measures must be devised to overcome barriers to the implementation of such regulations. One of these measures is the use of AI, which is analyzed with the aim of improving enforcement conditions and enhancing compliance with international environmental rules, in order to determine whether AI can remedy weaknesses in the implementation of international environmental laws. The research method is descriptive-analytical, and data were collected through a library-based approach. The writing draws upon sources such as international environmental conventions and treaties, books and journals in the field of artificial intelligence, and relevant specialized articles. The gathered data were subsequently analyzed. It is expected that AI—through monitoring compliance with international environmental regulations, identifying and predicting environmental risks, analyzing datasets, and supporting more sustainable decision-making—will facilitate the enforcement of international environmental law. These findings may contribute to improving the implementation of international environmental regulations.

Keywords: Artificial intelligence; Technological tools; Enforcement; International law; Environment.

Received: 01 July 2025

Revised: 10 November 2025

Accepted: 17 November 2025

Initial Publish: 29 November 2025

Final Publish: 01 April 2026



Copyright: © 2026 by the authors. Published under the terms and conditions of Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License.

Citation: Yousofi Majd, M., Norouzi, M., & Tayebi, S. (2026). Feasibility of Artificial Intelligence in the Enforcement of International Environmental Law. *Legal Studies in Digital Age*, 5(2), 1-13.

1. Introduction

Today, with the advancement of new technologies in the field of environmental protection, promising technological tools have emerged for monitoring and protecting the environment, and through these innovative tools, significant contributions have been made to environmental preservation. In an era defined by unprecedented environmental challenges and evolving threats to environmental health, the use of advanced technologies for developing effective strategies to safeguard environmental health and safety has become essential (Allioui et al., 2023). Among these, artificial intelligence (AI) has emerged as a transformative

force, offering innovative solutions for monitoring, predicting, and mitigating environmental risks while enhancing the safety and welfare of societies (Gao et al., 2023).

It appears that AI can also contribute to improving the enforcement and compliance of international environmental law. Although research has been conducted on the role of such tools in environmental management and in the development of international environmental law, comprehensive research specifically addressing the use of AI for compliance with and enforcement of international environmental law—particularly environmental treaties—remains limited. Despite the fact that environmental regulations worldwide have significantly expanded over recent decades, and that since 1973 environmental legislation and organizations have grown substantially, the implementation of and compliance with international environmental law have often been unsuccessful. According to the *United Nations Environment Programme* report in January 2019, global environmental governance suffers from weak enforcement, which exacerbates environmental threats. Non-implementation and non-compliance with these regulations constitute one of the greatest challenges to mitigating climate change, reducing pollution, and preventing the widespread loss of species and habitats. Experts point to an alarming trend of increasing resistance to environmental regulations. This situation is undoubtedly concerning for the future of the planet, and therefore, measures must be adopted to remove obstacles to the implementation of international environmental rules. One such measure is the use of technological tools, among which AI plays a significant role (Ta'Amnha et al., 2024).

Given the challenges associated with enforcing environmental regulations, the importance of investigating the feasibility of AI as a technological tool for improving compliance with and enforcement of international environmental law becomes evident. This tool is examined with the goal of enhancing implementation conditions and promoting adherence to international environmental regulations, in order to determine whether AI can address weaknesses in the enforcement of international environmental law and guide international actors toward compliance. In other words, how can this technological tool improve the effectiveness of implementing and complying with international environmental law? (Abrokwah-Larbi & Awuku-Larbi, 2024).

The distinction between this research and previous studies lies in the fact that the present study examines AI specifically for its potential to enhance implementation and compliance within international environmental law. Previous studies have generally focused on environmental management, development of international environmental law, technology transfer, AI investment, or challenges associated with AI, rather than its application for legal compliance in environmental treaties (Naradda Gamage et al., 2020).

Of course, numerous factors contribute to the weak enforcement of environmental law, including poor coordination among government agencies, limited institutional capacity, lack of rapid access to information regarding environmental risks, weak civic engagement, and ineffective monitoring. It is therefore necessary to examine how and to what extent AI can improve these shortcomings in the enforcement of international environmental law. First, however, it is essential to define AI and international environmental law and to examine the relationship between the two (Allioui et al., 2023).

2. The Concept of Artificial Intelligence and International Environmental Law

Artificial intelligence began in 1950 when Alan Turing, an English computer scientist, devised a test called the “imitation game,” later known as the Turing Test. The objective of this test was to assess the intelligence of a computer and compare it with human intelligence. His conclusion was notable: machines could think like humans. Since then, AI-related inventions have emerged and expanded, including early applications such as chess programs (Brynjolfsson et al., 2011).

AI is a subfield of computer science focused on developing algorithms and computer programs capable of performing activities such as sensing, reasoning, learning, and decision-making—tasks that traditionally require human intelligence (Bharadiya, 2023). According to experts, AI refers to systems or machines that perform tasks typically requiring human intelligence and are capable of improving themselves over time based on collected data (Asif et al., 2021). Some also consider AI a computational system modeled after the human brain and nervous system (Chi & Gursoy, 2009). AI can play a role in addressing environmental challenges, from designing energy-efficient buildings and monitoring deforestation to optimizing renewable energy deployment, as well as large-scale applications such as satellite-based monitoring of greenhouse gas

emissions and smart homes that autonomously manage energy use (Ellahham et al., 2020). AI technologies are therefore associated with tools capable of performing human-like cognitive functions such as planning and learning (Siew et al., 2017).

AI is sometimes mistakenly used interchangeably with machine learning, although machine learning is in fact a broad and highly practical subfield of AI that enables systems to make rational decisions by processing large datasets through algorithms modeled after human cognition (Goodell et al., 2021).

International environmental law refers to a collection of legal principles, treaties, conventions, and agreements aimed at addressing global environmental challenges. It establishes a framework for cooperation and coordination among states to protect the environment, prevent pollution, and promote sustainable development. This field covers a wide range of issues, including climate change, biodiversity conservation, marine pollution, air pollution, hazardous waste management, and the protection of natural resources (Allioui et al., 2023).

International environmental law has emerged as a regulatory response to environmental protection and management. From the early stages of environmental awareness to contemporary debates on sustainability, environmental law has evolved into a comprehensive framework aimed at balancing economic growth with environmental protection. This framework comprises international agreements, national legislation, and principles designed to prevent, reduce, and remedy environmental harm across various sectors (Gao et al., 2023).

Advancements in AI offer opportunities for international law experts to consider how AI affects international law and how international law may regulate or be influenced by AI. AI tools may assist governments in enforcing international law. For instance, a state may deploy sensors to detect violations of arms treaties and employ AI to monitor these sensors. Therefore, how does AI relate to international environmental law, a relatively new branch of public international law? (Kanaan et al., 2024).

Environmental regulations—whether domestic laws or international treaties—have consistently considered technological and developmental aspects, often emphasizing scientific research for the future. AI is thus part of this broader technological orientation (Asad et al., 2024).

One of the defining characteristics of international environmental law is its reliance on **soft law**, meaning that this body of law often lacks strong binding enforceability; however, it has progressively moved toward “hard law” norms. Environmental regulations are complex, time-consuming, and costly to implement. The question, therefore, is through what mechanisms AI can make environmental regulations more effective and efficient. The following sections examine ways in which AI can enhance the enforcement of international environmental law (Tolstoy et al., 2023).

3. Monitoring Compliance with International Environmental Law

One of the applications of artificial intelligence in improving the enforcement of international environmental law is monitoring compliance with environmental regulations. AI-based compliance tools rely on large datasets and complex algorithms, raising questions about transparency, accountability, and potential bias in decision-making (Elgendy et al., 2022). There are various types of AI-based legal compliance mechanisms, which are examined below.

System-learning-based automation for compliance: Machine learning algorithms are used to automate compliance processes by analyzing large volumes of monitoring data. These algorithms can identify potential compliance risks, track transactions for anomalies, and predict non-compliance issues before they occur (Allioui et al., 2023).

AI-based predictive analytics for risk assessment: Predictive analytics use historical compliance data to forecast potential legal risks. AI systems analyze compliance patterns to provide early warnings about possible violations (Goodell et al., 2021).

Natural language processing (NLP) for regulatory analysis: AI makes it possible to interpret and process the texts of international legal instruments, contracts, and regulatory documents. This technology can automatically review contractual compliance, identify inconsistencies, and ensure that international environmental policies and rules are aligned with regulatory requirements (Elgendy et al., 2022).

Robotic process automation (RPA) for compliance reporting: Through RPA, repetitive compliance tasks such as data entry, reporting, and document validation are automated, reducing human error and accelerating compliance workflows (Siew et al., 2017).

In all these forms of AI-based legal compliance, such tools can be used to support effective enforcement of environmental laws and promote adherence to them (Brynjolfsson et al., 2011).

In light of the above types of AI-based legal compliance, some of the key advantages of AI in monitoring compliance with environmental regulations can be outlined. Automated AI-driven compliance reviews are transforming how environmental regulations are monitored and enforced (Allioui et al., 2023).

AI-based platforms continuously monitor environmental data to ensure compliance with regulations derived from international agreements. They can, for example, analyze greenhouse gas emission data from factories, water quality measurements from treatment plants, and other relevant metrics to detect non-compliance with established standards (Gao et al., 2023).

By automating these processes, AI reduces the need for manual inspections and enables more consistent and large-scale monitoring. AI systems can schedule and conduct routine compliance checks and audits without human intervention. These systems automatically collect data, analyze them, and generate reports based on the results (Prentice et al., 2020).

Another key benefit of AI in monitoring compliance with international environmental law is its capacity to facilitate real-time monitoring and enforcement. AI systems can be used to maintain air and water quality and detect illegal waste discharge. By providing real-time data, AI can help enforcement bodies in states and international organizations quickly identify areas requiring intervention, leading to more effective and efficient enforcement efforts (Ellahham et al., 2020).

This clearly poses challenges for enforcement agencies in terms of prioritizing performance objectives, allocating on-site resources, and managing reputational risks. For example, by analyzing drone footage, satellite images, and social media posts, AI can help optimize resource deployment by selecting locations where manual inspection would be most beneficial (Tanguturi & Muley, 2023).

However, the successful integration of AI into environmental law enforcement requires adapting legal systems to effectively incorporate AI tools. Legal frameworks must evolve to recognize and utilize AI-generated data and reports. This includes the following elements (Ta'Amnha et al., 2024):

- (a) Legal updates: Amending environmental laws to allow the use of AI in monitoring and enforcement.
- (b) Standardization: Developing standards for the use of AI in environmental compliance, including data accuracy requirements, reporting formats, and validation procedures (Siew et al., 2017).
- (c) Training for legal professionals: Training judges, lawyers, and regulatory officials on the capabilities and limitations of AI to ensure that they can effectively interpret AI-generated evidence (Oyewobi et al., 2016).

In addition, challenges related to data security and privacy raise further concerns. For instance, AI models may inherit biases from the data on which they are trained, resulting in unbalanced outcomes. Addressing such bias requires the use of diverse and representative datasets, regular auditing of AI algorithms for fairness, and incorporation of feedback loops to improve the system's accuracy and equity over time (Naradda Gamage et al., 2020).

Thus, despite the promising applications of AI in legal compliance, concerns regarding ethical implications, data privacy, and regulatory acceptance remain. To address these concerns, AI-based environmental data should be made publicly accessible to strengthen accountability and public engagement. Furthermore, regulatory authorities in different jurisdictions are still in the process of formulating policies to oversee the use of AI in compliance management (Yaiprasert & Hidayanto, 2023).

While AI enhances efficiency, businesses and institutions must navigate regulatory uncertainties and ethical considerations to ensure the responsible adoption of AI (Abrokwah-Larbi & Awuku-Larbi, 2024).

Addressing these challenges is crucial for building trust and maximizing the benefits of AI-based legal compliance. The final part of this article will therefore examine these issues in greater detail.

4. Monitoring Compliance with International Environmental Law

4.1. *Effective Regulatory Frameworks*

International environmental law must keep pace with technological innovations in AI, adapt to new realities, and create clear and effective regulatory frameworks. In this regard, international rules and regulations—especially treaties—must be carefully drafted to ensure environmental protection without obstructing innovation. Flexibility to adapt to technological change and to the specific needs of each sector is therefore essential (Ta'Amnha et al., 2024).

Global governance and international cooperation are indispensable for addressing transnational challenges such as climate change and ocean pollution. International agreements and cooperative mechanisms are necessary to ensure an effective and coordinated response. Moreover, sharing knowledge, technology, and resources among states is crucial for the success of global environmental protection efforts (Asad et al., 2024).

The Paris Agreement, within the framework of international climate change law and specifically under the United Nations Framework Convention on Climate Change, explicitly stipulates in Article 3 that state parties are obliged to respect certain principles. For the effective implementation of this article and to guide states in complying with these principles, AI has the potential to support the design of effective regulatory monitoring frameworks (Kanaan et al., 2024).

4.2. *The Supervisory Role of Artificial Intelligence in the Enforcement of International Environmental Law*

Traditional methods of environmental monitoring, while at times successful, are often limited in scale and in their capacity to process vast volumes of data. Conventional inspections and observational techniques face difficulties in keeping pace with the rapid changes occurring within ecosystems. Moreover, the sheer complexity of interconnected environmental systems makes it nearly impossible to gain a comprehensive understanding using only traditional methods (Allioui et al., 2023).

In this context, the need to interpret patterns in monitoring and conservation through innovative technological methods becomes apparent. Here, AI emerges as a beacon of hope amid environmental disruption. With its capacity for advanced data processing, pattern recognition, and predictive analytics, AI promises a revolution in environmental monitoring and conservation. At the core of AI's transformative potential lies its ability to convert vast and complex environmental datasets into actionable insights (Gao et al., 2023). Through sophisticated algorithms and machine learning models, AI can detect patterns that conventional methods fail to identify.

AI thus acts as a transformative force. To illustrate this point, consider examples that clearly demonstrate AI's tangible role in protecting ecosystems: tracking the routes of illegal elephant poaching in Africa, or detecting unlawful logging activities in the Amazon rainforest—contexts in which AI emerges as a guardian of biodiversity and a catalyst for sustainable environmental practices (Prentice et al., 2020).

Another example is wildlife tracking, a vital endeavor for understanding the complex behavioral patterns of diverse species. Traditional methods, such as manual tracking and observational data, are limited and often insufficient to capture this richness of information. The emergence of AI has revolutionized wildlife monitoring by injecting unprecedented capabilities into the observation and interpretation of animal movements (Bharadiya, 2023).

Habitat assessment provides another illustration: forests, intricate wetland networks, and other ecosystems form the beating heart of biodiversity. The health of these ecosystems is crucial for the survival of countless species and the delicate balance of nature. Assessing habitat vitality and identifying areas in need of restoration require a level of insight beyond human capacity. AI offers an “aerial lens” through advanced image analysis—often driven by convolutional networks—that reveals the hidden dynamics of diverse ecosystems (Yaiprasert & Hidayanto, 2023).

AI's ability to rapidly and accurately process massive datasets is a game changer for habitat assessment, overcoming the constraints of manual surveys and traditional monitoring methods. This technology provides a comprehensive view of ecosystems, from regional to even global comparisons, enabling a dynamic and real-time understanding of habitat health. The impact of AI on habitat assessment is particularly evident in the Amazon rainforest, where the battle against illegal logging is intense. Through the “sharp eyes” of AI, satellite imagery is transformed into a treasure trove of information. AI algorithms

analyze data with a precision beyond human capability, identifying subtle indicators of illegal logging activities (Goodell et al., 2021).

AI is capable of automatically and rapidly analyzing big data to uncover hidden patterns and complex relationships (Mehrani et al., 2022). In other words, AI can, by analyzing data from various sources—including satellite imagery, sensors, drone footage, and social media—support the monitoring of compliance with international environmental treaties and regulations by obligated actors and enable the identification of patterns and trends. Remote sensing technologies such as satellites and radar provide precise, real-time data on deforestation, pollution, overfishing, and other environmental issues. Drone-based cameras and sensors facilitate data collection in hard-to-reach areas such as tropical forests and glaciers (Tanguturi & Muley, 2023).

Advanced algorithms can predict areas at high risk of deforestation, identify pollution hotspots, and monitor the health of oceans. As technological innovations emerge at a rapid pace, they challenge existing regulatory frameworks and require a proactive approach to ensuring environmental protection as envisaged in international environmental agreements (Ta'Amnha et al., 2024).

Satellite-based monitoring systems, electronic surveillance, and real-time tracking tools help authorities detect and prevent unauthorized activities in protected areas. These technologies provide valuable evidence for legal action in enforcing international environmental law and act as a deterrent to potential violators (Siew et al., 2017).

AI has the potential to transform the landscape of international environmental law enforcement and decision-making. By enabling real-time monitoring and enforcement, AI can identify environmental violations more efficiently and effectively and support timely responses. This, in turn, can lead to better outcomes for the environment as well as for human health and safety (Ellahham et al., 2020).

AI technologies can be understood as tools for both climate mitigation and adaptation. This intersection includes efforts to actively use AI technologies to reduce greenhouse gas emissions and slow global warming, as well as to enhance the resilience of communities to the impacts of the climate crisis. Examples of AI-based mitigation and adaptation initiatives include data-driven sensor and satellite technologies designed to monitor and reduce air pollution in smart cities, and to improve the precision of agricultural practices as part of smart farming systems (Siswanti et al., 2024).

5. Prediction of Environmental Risks

One of the environmental risks is the destruction of the ozone layer caused by the consumption of ozone-depleting substances. Current ozone monitoring systems rely heavily on satellite instruments and meteorological balloons equipped with radiosondes. Although these instruments provide valuable data, they face multiple challenges, including delayed data reporting: most satellite data are batch-processed, which leads to time lags ranging from several hours to several days before public access becomes possible, and inadequate predictive capabilities: traditional systems often report only past or near-real-time ozone concentrations and struggle to forecast future fluctuations without complex modeling infrastructures (Elgendy et al., 2022). In this context, the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer, as one of the key treaties of international environmental law, sets its objective as the protection of the ozone layer through forecasting, establishing controls, and defining criteria for regulating global emissions of ozone-depleting substances (Ta'Amnha et al., 2024).

Artificial intelligence (AI) provides powerful tools for transforming ozone monitoring and forecasting. AI systems are inherently adaptive, data-driven, and capable of modeling nonlinear relationships—all of which are crucial for analyzing atmospheric dynamics (Goodell et al., 2021).

Predictive modeling: Algorithms such as random forests, recurrent neural networks (RNNs), and long short-term memory (LSTM) networks can be trained on multidimensional datasets—including meteorological conditions, emission patterns, and satellite imagery—to forecast ozone concentrations across both time and space (Gao et al., 2023).

Anomaly detection: AI systems can be configured to automatically detect unusual drops or spikes in ozone levels, thereby helping to identify illegal emissions of ozone-depleting substances or the onset of extreme weather events (Prentice et al., 2020).

Data fusion and optimization: AI excels at integrating heterogeneous data sources—such as IoT sensor feeds, satellite telemetry, and chemical simulation models—and enhancing accuracy and reliability through continuous retraining loops (Elgendy et al., 2022).

Edge intelligence: Lightweight AI models embedded in Internet of Things (IoT) devices can process data locally and in real time, reducing dependence on centralized or cloud-based computation and enabling ozone monitoring even in under-resourced regions (Siswanti et al., 2024).

A validation study using a 10-year retrospective dataset (2010–2020) from the World Ozone and Ultraviolet Radiation Data Centre (WOUDC) showed that the AI module reduced the mean absolute error (MAE) by approximately 27% compared with traditional numerical prediction models (Brynjolfsson et al., 2011).

5.1. *Forecasting Natural Disasters and Early Warning Systems*

AI has emerged as a “seer” in forecasting natural disasters, transforming our ability to anticipate and respond to environmental threats (Naradda Gamage et al., 2020). In this regard, data analytics, real-time environmental measurements, AI models, and early warning systems jointly provide unprecedented accuracy in predicting natural disasters (Allioui et al., 2023).

For example, in the United States, the Federal Emergency Management Agency (FEMA) uses predictive modeling to assess the vulnerability of regions to natural disasters and employs AI to support disaster management. AI assists in preventive planning, resource allocation, and evacuation strategies, thereby helping to reduce disaster impacts on communities (Abrokwah-Larbi & Awuku-Larbi, 2024). These models, powered by machine learning algorithms, form the backbone of robust early warning systems that enable proactive responses to imminent disasters.

The predictive power of AI is dynamic and evolves through continuous learning from historical data and real-time inputs. This adaptability ensures that forecasts remain accurate even as environmental conditions change. Integration of AI models into early warning systems generates comprehensive and timely predictions of impending natural disasters. Another striking example of AI as a “predictor” appears in the implementation of flood-forecasting systems in coastal areas. Historical records provide valuable insight into the factors influencing floods and prepare the ground for predictive modeling. AI’s predictive capabilities go beyond historical data by incorporating real-time weather conditions into its models. By continuously monitoring meteorological variables such as rainfall patterns, wind behavior, and atmospheric pressure, AI adjusts its forecasts in response to emerging environmental dynamics and improves the accuracy of flood predictions (Siswanti et al., 2024).

There are numerous practical examples in this field. As a practical case, the U.S. Environmental Protection Agency (EPA), in cooperation with technology companies, has deployed AI-based sensor networks in urban areas to monitor air quality in real time. This system provides timely data on air pollutants and, through predictive analysis, enables preventive measures to combat pollution. The initiative has led to improvements in air-quality indicators and influenced targeted policy interventions (Gao et al., 2023).

Another example is that the United States Geological Survey (USGS) uses AI-based programs to analyze water-quality data from various sources, including satellite imagery and ground-based sensors. AI-driven analysis enhances understanding of water-quality trends and helps authorities identify pollution sources and formulate effective water-management strategies (Tanguturi & Muley, 2023).

5.2. *Benefits of AI-Based Natural Disaster Prediction*

The use of big data and sophisticated AI algorithms enables governments and international environmental organizations to employ AI-based predictions, consistent with international treaties, for more precise monitoring and management of forests, rangelands, and wildlife habitats (Ta'Amnha et al., 2024). Some organizations already use AI to identify and protect endangered species and monitor habitat destruction.

The 62nd session of the United Nations General Assembly, by adopting a resolution entitled “Non-Legally Binding Instrument on All Types of Forests” (commonly referred to as the forest instrument), took another significant step toward

sustainable forest protection and utilization worldwide. The first global objective of this legal instrument includes reversing the loss of forest cover worldwide through sustainable forest management, including conservation, restoration, afforestation and reforestation, and preventing forest degradation.

How, then, can AI contribute to the implementation of this instrument of international environmental law in pursuit of that global goal?

Machine learning algorithms in AI can analyze satellite data to predict environmental risks such as deforestation or forest fires (Prentice et al., 2020). AI also helps in tracking and preventing environmental degradation. Using AI algorithms and models, it is possible to forecast processes such as forest fires or illegal logging. This information can assist environmental authorities in taking appropriate measures to prevent such damage (Siew et al., 2017).

AI can further help predict environmental risks such as oil spills or natural disasters by analyzing historical data and current conditions. This supports environmental enforcement agencies in preparing for potential incidents and responding more quickly and effectively.

AI also plays a positive role in wildlife conservation. By using AI-based technologies, endangered animals can be identified and monitored more effectively (Bharadiya, 2023).

As a result, AI technology is capable of identifying or predicting potential violations of environmental law that entail environmental risk. Regulated organizations may be subject to closer oversight and more intensive monitoring, particularly where AI provides a cost-effective method for identifying potential breaches of environmental regulations (Allioui et al., 2023).

As previously noted, AI can forecast weather and, by addressing wide-ranging challenges—such as predicting storms, floods, and droughts, simulating climate conditions and their social and economic consequences—can provide more accurate global and local climate reports. AI creates new opportunities for understanding extensive datasets generated by numerous component-based climate models. It can combine projected conditions from around 30 climate models using computer-learning algorithms. By improving the accuracy of global climate simulations, AI reduces and manages the risks of natural disasters such as extreme weather events. AI algorithms enhance readiness for environmental hazards, particularly when rapid, intelligent decision-making is critical (Goodell et al., 2021).

Under the 2015 Paris Agreement, in enhancing the implementation of the Convention, one of the central objectives is to strengthen the global response to the threat of climate change in the context of sustainable development, including: keeping the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change. How, then, can AI contribute to the implementation of this international environmental agreement and this specific objective?

AI algorithms are used not only for local natural events but also for global phenomena, providing coordinated projections of how actual temperature changes relate to the 2°C threshold. When a neural network is supplied with monthly global temperature data from the past 30 years, it can successfully predict changes in heat over the next decade with very high accuracy (Elgendy et al., 2022). AI can also help clarify the drivers of climate change. Using satellite imagery, AI can identify and map sources of carbon-dioxide emissions in countries that are unwilling or not yet obliged to submit detailed emission reports (Tanguturi & Muley, 2023).

5.3. *Barriers and Challenges of AI-Based Natural Disaster Prediction*

Despite the advantages of AI-based natural disaster prediction, several issues must be resolved to ensure its successful application. The quality of the data used for analysis is one of the main obstacles. For AI systems to make accurate predictions and decisions, they require precise and reliable data. Poor-quality data can lead to incorrect predictions and flawed decisions that may affect property and public safety (Elgendy et al., 2022).

At the core of AI's effectiveness in environmental monitoring and protection lies the quality and availability of data. The success of AI programs depends on access to comprehensive and accurate environmental datasets; however, this fundamental requirement poses challenges in many parts of the world. Variability in data quality hampers the development and deployment

of robust AI models and limits their ability to deliver precise insights and forecasts. Addressing the challenge of unstable data quality requires coordinated efforts to strengthen data-collection infrastructures. This includes strategic investment in advanced technologies such as sensor networks, satellite systems, and ground-based monitoring to collect high-resolution, timely data. Collaboration among governments, research institutions, and technology companies in establishing standardized data-collection protocols is crucial. Such a collaborative approach ensures the development of a strong foundation of high-quality data for AI applications (Kanaan et al., 2024).

Data access presents another difficulty. Building accurate and reliable AI-based prediction systems is challenging where regions lack sufficient historical data on natural disasters. Beyond technological limitations, political and economic factors may also affect data availability. Moreover, the use of AI for natural disaster prediction raises concerns about privacy, data ownership, and the potential misuse of data. Therefore, to ensure trustworthy AI in natural disaster prediction, appropriate regulations and ethical guidelines must be developed (Ta'Amnha et al., 2024).

6. Policymaking for the Drafting and Implementation of International Environmental Regulations

Today, numerous international treaties and laws concerning the environment have been concluded, yet despite this significant growth in the adoption of legal instruments, the implementation of these treaties remains weak. The accumulation of laws and regulations that are not effectively implemented results in little more than a waste of time and does not meaningfully contribute to environmental protection. One of the areas in which artificial intelligence (AI) has the potential to assist in enforcing international environmental law is policymaking for the drafting of laws and regulations. How can AI be effective in this regard? (Allioui et al., 2023)

To begin with, policymaking is a highly complex process that takes place in changing environments and affects the three pillars of sustainable development: society, economy, and environment. Every domestic and international political decision in fact entails a form of social reaction, influences the economic and financial aspects of states, and has significant environmental consequences. Improving decision-making in this domain can have substantial positive impacts on all these dimensions (Ta'Amnha et al., 2024).

In general, the policymaking process passes through four stages: policy planning, environmental assessment, implementation, and monitoring. The first three stages are carried out *ex ante*, in a predictive mode. At the planning stage, strategic objectives are defined, budgetary constraints—whether those of international organizations or of individual states—are set, and geophysical limitations are taken into account. The assessment stage, which traditionally follows planning, concerns the evaluation of the environmental impact of the proposed policy scheme and, to some extent, its impact on the global economy and society. Implementation involves defining a set of instruments to support the planned objectives, such as incentives, information campaigns, tax exemptions in states, and coercive measures. The monitoring stage, carried out after implementation, examines whether the enforcement strategies have achieved the expected objectives defined at the planning stage (Elgendy et al., 2022).

Improving decision-making at each of these stages can have a significant positive impact on all aspects of sustainable development. Several AI techniques can play an important role in enhancing the policymaking process in these stages, including decision-support and optimization methods, data mining, simulation, and related modeling approaches (Siew et al., 2017).

One of the AI techniques that can play a major role in improving the policymaking process—and which is highlighted in this discussion—is “simulation.” Research indicates that AI can assist policymakers by simulating different scenarios and predicting outcomes, thereby helping them to evaluate the impact of proposed policies and regulations. AI can also support policymakers in monitoring the effectiveness of existing policies and identifying areas for improvement. This means that before drafting an international environmental law or concluding an international environmental treaty, AI can simulate different scenarios of that legal instrument and forecast its expected outcomes. These predicted outcomes will indicate the degree of effectiveness and efficiency of the proposed law. If the predicted results are beneficial, policymakers and drafters may proceed to adopt and codify the treaty; otherwise, if the simulated scenarios yield negative or unsatisfactory results, the law can be discarded. In this way, beyond contributing to the drafting of more standardized rules, AI can help prevent the proliferation of numerous low-quality laws and treaties that add little value (Allioui et al., 2023).

Moreover, policymakers must maintain a holistic view of policy, taking into account financial dimensions, objectives, environmental impacts, and constraints, and must generate alternative scenarios. Society, for its part, can participate in the policymaking process through electronic participation (e-participation), both at the pre-legislative stage and afterwards, by providing feedback on different scenarios. It is clear that a balance must be established between global and individual perspectives. In this regard, AI-based modeling and analysis can contribute to reconciling these perspectives ([Naradda Gamage et al., 2020](#)).

On the other hand, every technology has its advantages and disadvantages, and its use requires the adoption and implementation of appropriate rules and regulations. In the field of international environmental law, it is therefore the responsibility of international institutions, with the cooperation and consent of states, to examine and regulate how AI may be used. By following such a process, AI can be harnessed to advance international environmental law and to support relations among states and also among peoples, and many of the challenges currently present in the field of international environmental protection may be resolved. AI has the capacity to technically and legally analyze various parameters in the drafting and adoption of international environmental norms and to propose professional and context-sensitive rules to states and peoples for implementation—rules that can then be adopted and put into practice within public forums and international organizations such as the United Nations ([Kanaan et al., 2024](#)).

The outcomes of the United Nations AI summit in Geneva in 2017 showed that AI may bring about positive changes in all aspects of human life. This indicates that AI is seen as a means of fundamentally improving human welfare in support of comprehensive measures for protecting the natural environment. Nevertheless, although AI is increasingly penetrating commercial, military, and scientific domains, states have been slow to conclude new international environmental agreements or to revise existing treaties so as to keep pace with these technological advances. The use of AI for environmental protection requires cooperation between environmental experts and technologists. Social, political, and economic factors must also be taken into account to ensure that the use of AI in environmental protection serves the aims of sustainable development and improved quality of life for people ([Asad et al., 2024](#)).

7. Challenges of Artificial Intelligence Technology

Although AI has the potential to assist in the enforcement of international environmental law in numerous areas—such as supporting monitoring, protecting and managing natural resources, aiding control and mitigation efforts, predicting and preventing climate-related problems, promoting more efficient and sustainable food systems, and accelerating the adoption of sustainable energy, as discussed in earlier sections of this article—unfortunately, AI itself also has environmental risks that must be taken into account in any assessment. Current analyses identify four categories of environmental risks: greenhouse gas emissions linked to electricity consumption; the need for rare metals (such as cobalt and silicon) for manufacturing servers and electronic chips; environmental impacts associated with data-center operations (including heat generation, electricity consumption, and water use for cooling); and negative effects related to the deployment of AI systems that increase the environmental footprint of other sectors. All these potential consequences must be integrated into the impact assessment outlined earlier ([Goodell et al., 2021](#)).

Legal frameworks under international law must be established to regulate and mitigate the negative impacts of AI on environmental protection. These include, among others: (1) rules to prevent adverse environmental effects of AI; (2) rules to control environmental pollution arising from the deployment of AI; (3) rules for the protection of natural resources; and (4) rules for addressing legal violations related to negative environmental impacts of AI ([Ta'Amnha et al., 2024](#)).

In addition, the use and implementation of AI in international environmental law involve other challenges. These include risks stemming from misuse of the technology; ethical issues related to automated decision-making; system failures in AI applications; cybersecurity concerns; improper deployment of technologies; privacy issues; high technological costs; dependence on data and software-based analytics; legal challenges related to data use; reduced human involvement in decision-making processes; and, most importantly, global challenges in supervising AI, the absence of harmonized global standards for its use, misuse of collected data, and particularly the cultural and social difficulties associated with the acceptance of the technology. All these factors can challenge the use of AI in promoting compliance with international environmental law. It is

therefore clear that decisions made by AI systems are open to contestation—for example, drone images or satellite data may be misprocessed by AI technologies (Naradda Gamage et al., 2020).

Ethical issues related to the use of AI likewise create serious challenges. AI systems must be designed and implemented in ways that ensure transparency, accountability, and fairness. The deployment of AI for sustainable development must prioritize ethical frameworks and guidelines to prevent unintended consequences and biases. Overall, the implementation of AI for sustainability and environmental resilience requires addressing challenges related to data access, interdisciplinary cooperation, and ethical considerations (Siswanti et al., 2024).

Some ethical risks arise from the way AI models are designed and developed. Most data-driven approaches are trained on existing labeled datasets to provide a basis for learning to classify, predict, or decide on new data. This raises the possibility that unintended biases may be introduced into the decisions that an AI system ultimately makes, increasing the risk of discrimination and unfair treatment of individuals or groups (Goodell et al., 2021).

The recommendations of the Paris Climate Agreement and of the United Nations Educational, Scientific and Cultural Organization (UNESCO) concerning ethical issues related to AI emphasize the need to align technological advances with global environmental responsibilities when analyzing the intersection of international climate agreements and the vital role of AI in addressing climate change. Reducing global warming is the central objective of the Paris Agreement, whose Article 10 recognizes the essential role of technology in preventing climate change (Elgendy et al., 2022).

In 2019, the European Commission published the “Ethics Guidelines for Trustworthy AI,” which set out a framework for the trustworthy development of AI. These guidelines list requirements that AI must meet in order to be considered trustworthy. A set of assessment tools has been proposed to help verify that each key requirement is fulfilled, including: human agency and oversight, privacy and data governance, robustness and safety, diversity, non-discrimination and fairness, social and environmental well-being, transparency, and accountability. AI must respect fundamental rights (Brynjolfsson et al., 2011).

Another key challenge for AI in environmental enforcement is the lack of comprehensive datasets required to train AI models. AI algorithms heavily depend on large and diverse datasets to produce accurate predictions and recommendations. However, such datasets are often scarce or incomplete in the context of sustainable development and environmental resilience, which can undermine the effectiveness of AI systems in identifying and addressing environmental issues (Kanaan et al., 2024).

A further challenge is the need for interdisciplinary cooperation and knowledge sharing. The application of AI in sustainable development requires collaboration among experts from various fields, including environmental science, computer science, and public policy. There is a strong emphasis on bringing together diverse expertise to develop AI solutions that are not only technologically sound but also aligned with the social and environmental needs of communities (Asad et al., 2024).

The first global AI law was adopted through an agreement on 21 March 2024 under the auspices of the United Nations, with the objectives of promoting human rights, monitoring risks, and protecting personal data. The international community is striving to establish legal frameworks that ensure environmental protection through the United Nations and its agencies. The potential of AI to improve the effectiveness of environmental regulation must be considered alongside ethical principles. This requires close cooperation among policymakers, researchers, and environmental bodies to ensure that AI is used in a transparent, fair, and environmentally protective manner.

Moreover, the use of AI in environmental protection necessitates cooperation between environmental specialists and technologists. Social, political, and economic factors must also be taken into account to ensure that AI is used in environmental protection in ways that promote sustainable development and improve quality of life. A further critical challenge is the lack of comprehensive datasets needed to train AI models. AI algorithms are highly dependent on large and diverse datasets to generate accurate predictions and recommendations, yet such datasets are often scarce or incomplete in the field of sustainable development and environmental resilience, which can hinder the effectiveness of AI systems in identifying and addressing environmental issues. The effectiveness of AI models depends heavily on data quality and availability; incomplete, biased, or inaccurate datasets can lead to flawed predictions and decisions (Naradda Gamage et al., 2020).

8. Conclusion

Based on the analyses conducted, it can be concluded that by harnessing the power of artificial intelligence, a higher level of environmental protection can be achieved, legal compliance can be strengthened, and a more sustainable future can be cultivated. The influence of artificial intelligence on all aspects of life—as well as on the implementation of international environmental law—is still in its early stages. In line with the objective of the 1987 Montreal Protocol, which aims to protect the ozone layer through forecasting and establishing controls and criteria for regulating the emission of ozone-depleting substances, the findings indicate that AI-based ozone prediction models significantly reduce errors compared to conventional techniques and provide higher accuracy in estimating ozone depletion rates.

Artificial intelligence has the potential to transform the landscape of international environmental law enforcement, particularly in monitoring compliance with international rules and agreements. It can assist in identifying illegal activities that harm the environment and facilitate the effective implementation of international environmental law. Through AI, international environmental regulations can be monitored, managed, and protected more efficiently and effectively, thereby easing their enforcement. This, however, requires the establishment of national, regional, and global data and information systems aligned with international environmental standards.

AI can support policymakers by simulating different scenarios and predicting outcomes, enabling them to assess the impact of proposed policies and regulations. The use of AI in implementing and complying with international environmental law—and in safeguarding the environment—requires cooperation among environmental experts, technologists, and legal scholars. Social, political, and economic factors must also be considered to ensure that AI is utilized in environmental protection in a way that promotes sustainable development and enhances the quality of life for communities.

Nevertheless, decisions generated by AI technologies may be subject to technical and ethical challenges, including risks of technological misuse, ethical concerns related to automated decision-making, privacy issues, and cultural and social challenges associated with technological acceptance. Therefore, any use of artificial intelligence must be guided by ethical principles.

Ethical Considerations

All procedures performed in this study were under the ethical standards.

Acknowledgments

Authors thank all who helped us through this study.

Conflict of Interest

The authors report no conflict of interest.

Funding/Financial Support

According to the authors, this article has no financial support.

References

- Abrokwah-Larbi, K., & Awuku-Larbi, Y. (2024). The impact of artificial intelligence in marketing on the performance of business organizations: Evidence from SMEs in an emerging economy. *J. Entrep. Emerg. Econ.*, 16, 1090-1117. <https://doi.org/10.1108/JEEE-07-2022-0207>
- Allioui, H., Mourdi, Y., Allioui, H., & Mourdi, Y. (2023). Unleashing the potential of AI: Investigating cutting-edge technologies that are transforming businesses. *Int. J. Comput. Eng. Data Sci.*, 3, 1-12.
- Asad, M., Aledeinat, M., Majali, T., Almajali, D. A., & Shrafat, F. D. (2024). Mediating role of green innovation and moderating role of resource acquisition with firm age between green entrepreneurial orientation and performance of entrepreneurial firms. *Cogent Bus. Manag.*, 11, 2291850. <https://doi.org/10.1080/23311975.2023.2291850>
- Asif, M. U., Asad, M., Kashif, M., & Abrar ul Haq, M. (2021). Knowledge Exploitation and Knowledge Exploration for Sustainable Performance of Smes. 2021 Third International Sustainability and Resilience Conference: Climate Change, <https://doi.org/10.1109/IEEECONF53624.2021.9668135>
- Bharadiya, J. P. (2023). Machine learning and AI in business intelligence: Trends and opportunities. *Int. J. Comput.*, 48, 123-134.

- Brynjolfsson, E., Hitt, L. M., & Kim, H. H. (2011). Strength in Numbers: How Does Data-Driven Decisionmaking Affect Firm Performance? *SSRN Electron. J.* <https://doi.org/10.2139/ssrn.1819486>
- Chi, C. G., & Gursoy, D. (2009). Employee satisfaction, customer satisfaction, and financial performance: An empirical examination. *Int. J. Hosp. Manag.*, 28, 245-253. <https://doi.org/10.1016/j.ijhm.2008.08.003>
- Elgendy, N., Elragal, A., & Pääväranta, T. (2022). DECAS: A modern data-driven decision theory for big data and analytics. *J. Decis. Syst.*, 31, 337-373. <https://doi.org/10.1080/12460125.2021.1894674>
- Ellahham, S., Ellahham, N., & Simsekler, M. C. E. (2020). Application of Artificial Intelligence in the Health Care Safety Context: Opportunities and Challenges. *Am. J. Med. Qual.*, 35, 341-348. <https://doi.org/10.1177/1062860619878515>
- Gao, L., Li, G., Tsai, F., Gao, C., Zhu, M., & Qu, X. (2023). The impact of artificial intelligence stimuli on customer engagement and value co-creation: The moderating role of customer ability readiness. *J. Res. Interact. Mark.*, 17, 317-333. <https://doi.org/10.1108/JRIM-10-2021-0260>
- Goodell, J. W., Kumar, S., Lim, W. M., & Pattnaik, D. (2021). Artificial intelligence and machine learning in finance: Identifying foundations, themes, and research clusters from bibliometric analysis. *J. Behav. Exp. Financ.*, 32, 100577. <https://doi.org/10.1016/j.jbef.2021.100577>
- Kanaan, O. A., Alsoud, M., Asad, M., TaAmnha, M. A., & Al-Qudah, S. A. (2024). mediated moderated analysis of knowledge management and stakeholder relationships between open innovation and performance of entrepreneurial firms. *Uncertain. Supply Chain. Manag.*, 12, 2383-2398. <https://doi.org/10.5267/j.uscm.2024.5.028>
- Mehrani, A., Alizadeh, H., & Rasouli, A. (2022). Evaluating the Role of Artificial Intelligence Tools in Developing Financial and Marketing Services.
- Naradda Gamage, S. K., Ekanayake, E., Abeyrathne, G., Prasanna, R., Jayasundara, J., & Rajapakshe, P. A. (2020). Review of Global Challenges and Survival Strategies of Small and Medium Enterprises (SMEs). *Economies*, 8, 79. <https://doi.org/10.3390/economies8040079>
- Oyewobi, L. O., Windapo, A., & Rotimi, J. O. B. (2016). Relationship between decision-making style, competitive strategies and organisational performance among construction organisations. *J. Entrep. Emerg. Econ.*, 16(4), 713-738. <https://doi.org/10.1108/JEEE-07-2022-0207>
- Prentice, C., Weaven, S., & Wong, I. A. (2020). Linking AI quality performance and customer engagement: The moderating effect of AI preference. *Int. J. Hosp. Manag.*, 90, 102629. <https://doi.org/10.1016/j.ijhm.2020.102629>
- Siew, L. W., Wai, C. J., & Hoe, L. W. (2017). Data Driven Decision Analysis in Bank Financial Management with Goal Programming Model. *Advances in Visual Informatics: 5th International Visual Informatics Conference, IVIC 2017*, https://doi.org/10.1007/978-3-319-70010-6_63
- Siswanti, I., Riyadh, H. A., Nawangsari, L. C., Mohd Yusoff, Y., & Wibowo, M. W. (2024). The impact of digital transformation for sustainable business: The meditating role of corporate governance and financial performance. *Cogent Bus. Manag.*, 11, 2316954. <https://doi.org/10.1080/23311975.2024.2316954>
- Ta'Amnha, M. A., Al-Qudah, S., Asad, M., Magableh, I. K., & Riyadh, H. A. (2024). Moderating role of technological turbulence between green product innovation, green process innovation and performance of SMEs. *Discov. Sustain.*, 5, 324. <https://doi.org/10.1007/s43621-024-00522-w>
- Tanguturi, R. N. V., & Muley, A. A. (2023). Enhancing Financial Institution Operations Through Data-Driven Decision-Making. *J. Namib. Stud. Hist. Polit. Cult.*, 39, 272-282.
- Tolstoy, D., Nordman, E. R., & Vu, U. (2023). The indirect effect of online marketing capabilities on the international performance of e-commerce SMEs. *Int. Bus. Rev.*, 31, 101946. <https://doi.org/10.1016/j.ibusrev.2021.101946>
- Yaiprasert, C., & Hidayanto, A. N. (2023). AI-driven ensemble three machine learning to enhance digital marketing strategies in the food delivery business. *Intell. Syst. Appl.*, 18, 200235. <https://doi.org/10.1016/j.iswa.2023.200235>