iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** VI **Month of publication:** June 2025

DOI: https://doi.org/10.22214/ijraset.2025.72111

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue VI June 2025- Available at www.ijraset.com

Harnessing Artificial Intelligence for Climate Governance: Legal Innovations and Challenges in Environmental Law

Simranpreet Kaur
Guru Nanak Dev University, India

I. INTRODCTION

Climate change, a gift of man's unprecedented growth and development, has become the worst enemy of the current and the coming generation. It affects the quality of life and places man on backfoot. It is a setback to the planet earth. The global phenomenon of climate change has become increasingly pronounced, resulting in myriad challenges ranging from extreme weather events to ecosystem disruptions.[1] Global temperature has risen by nearly 1.1 degrees Celsius since the pre-industrial era, as per the IPCC, resulting in more intense, frequent, and severe heat waves, storms, and other extreme weather.[2] This has caused great disturbance in the ecosystem and our home, which we call as 'environment'. It has another significant implication, the violation of environmental rights and the relevant laws concerning the environment. The accelerating climate crisis demands not only scientific and technological innovation but also robust legal frameworks capable of enforcing environmental protections, regulating emissions, and guiding sustainable development. The traditional approach to mitigate this climate change issue is to adapt new policies and sustainable practices. However, at the growth the issue is being proliferated, some sustainable practices and scattered policies will not be sufficient to cater to the needs of a healthy environment. Here, the role of new technologies like Artificial Intelligence becomes paramount. According to Britannica, artificial intelligence (AI), is the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings. It has the abilities to do the tasks efficiently and much more conveniently. It is being increasingly used in development of new technologies. In the context of environmental protection and climate change adaptations, research has proved that A.I. has great potential. In spheres such as climate science, regulations, and practice in the processing of huge amounts of data, allocation of resources and evidence-based decision-making, the artificial intelligence can be used to bring great change. Another advantage of using A.I. is the conservation of time, which is an urgent need of the hour, as the pace with which the issue of climate change is being accelerated, every moment is crucial. Thus, in that sphere, again, A.I. can yet again, be just the solution we have been asking for. However, on the other hand, among the AI applications strengths, there are of course the ethical, social and environmental problems related to their use in climate change solutions.[3] This chapter, thus delves into the dynamic relationship between AI and the climate crisis. It outlines the diverse roles AI can play in climate science, mitigation, and adaptation, examines real-world applications, and critically assesses the risks and limitations of AI-based interventions. By doing so, it aims to provide a holistic understanding of how AI can support a more sustainable, resilient, and equitable future—if deployed thoughtfully and inclusively, protecting environmental rights.

II. LEGAL FOUNDATIONS OF CLIMATE GOVERNANCE

Climate change is not a new concept, it has been recognized in different environmental conventions and world conferences headed by the then global leaders who identified the threat of the climate change looming over our home, planet earth like a dark cloud. Climate governance is rooted in a complex web of international agreements, national legislation, and local regulatory frameworks The first environmental conference, the Stockholm Conference, in 1972, however did not pay much attention to climate change.

[1] IPCC: Summary for policymakers. In Climate Change 2021: The Physical Science Basis. Edited by Masson-Delmotte V, Zhai P, Pirani A, Connors SL, Péan C, Berger S, Caud N, Chen Y, Goldfarb L, Gomis MI, et al.. Cambridge University Press; 2021:3-32 , https:// doi.org/10.1017/9781009157896.001
[2] M. C. Fisher et al., "Emerging fungal threats to animal, plant and ecosystem health," Nature, 484, no. 7393, pp. 186–194, Apr. 2012, doi: https://doi.org/10.1038/nature10947
[3] R. J. Zomer, A. Trabucco, D. A. Bossio, and L. V. Verchot, "Climate change mitigation: A spatial analysis of global land suitability for clean development mechanism afforestation and reforestation," Agriculture, Ecosystems & Environment, vol. 126, no. 1–2, pp. 67–80, Jun. 2008, doi: https://doi.org/10.1016/j.agee.2008.01.014. Available: https://www.sciencedirect.com/science/article/pii/S0167880908000169

In 1987, the Montreal Protocol highlighted the issue of greenhouse gases, which play a major role in climate change and committed towards the reduction of these greenhouse gases. Then in 1992, finally, the United Nation Framework Convention for Climate Change was adopted at the Rio Earth Summit.

- It is the foundational treaty of international climate law which greatly addressed the issue of climate change.
- It addressed established the principle that countries share responsibility for preventing dangerous anthropogenic interference with the climate system.
- Principles of cooperation, such as common but differentiated responsibilities and respective capabilities.

It was followed by the Kyoto Protocol in 1997 introduced legally binding emissions targets for developed nations, but its scope was limited and compliance mechanisms were weak.

- The Kyoto Protocol was the first international treaty to impose binding greenhouse gas emission targets—though only for industrialized countries.

In 2015, the Paris Agreement was passed which represents a legally binding treaty where all signatories submit Nationally Determined Contributions (NDCs), with a built-in system of global stocktakes and transparency frameworks.

- The Paris Agreement marked a pivotal shift in global climate governance. It is legally binding, but relies on self-determined contributions rather than top-down targets. Key features include:
- Nationally Determined Contributions (NDCs) submitted by each country;
- A Global Stocktake (GST) every five years to assess collective progress;
- The Enhanced Transparency Framework (ETF), requiring countries to submit standardized data on emissions and progress.

III. INDIA'S ROLE IN INTERNATIONAL CLIMATE LAW

India plays an important role in climate change mitigation and adaptation policies. As a developing nation with rising emissions, yet high vulnerability to climate impacts, its legal and diplomatic approach is rooted in the principles of equity and sustainable development. India is a party to the UNFCCC, Kyoto Protocol and Paris Agreement.

A. Constitutional Provisions

India's Constitution, while not originally drafted with environmental concerns in mind, has evolved to support environmental and climate action:

1) Article 48A (Directive Principles of State Policy): "The State shall endeavour to protect and improve the environment and to safeguard the forests and wildlife of the country." [4]

2) Article 51A(g) (Fundamental Duties): "It shall be the duty of every citizen of India to protect and improve the natural environment including forests, lakes, rivers and wildlife..."

3) Judicial Interpretations: The Supreme Court of India has interpreted the Right to Life (Article 21) to include the right to a healthy environment, which supports climate change mitigation and adaptation efforts. In M.K. RanjitSinh vs Union of India[5] , the Apex Court of India has finally laid down that for the first time recognized the right to a healthy environment and the right to be free from the adverse effects of climate change is a part of right to life.

IV. ARTIFICIAL INTELLIGENCE IN CLIMATE GOVERNANCE: CAPABILITIES AND CONSTRAINTS

A. Improving systems for greater energy efficiency

Artificial intelligence technology has progressively emerged as a new technological tool in the energy sector, offering novel prospects and challenges for ameliorating energy efficiency and realizing sustainable development.[6] AI-driven climate models offer one of the advantages of better representation of the complex climate systems of the globe. By teaching machine learning algorithms with historical climate data, they can create cleaner models of the interaction between the atmosphere, oceans, land surface, and biosphere[7].

[4] Constitution of India, 1950
[5] 2024
[6] Baysan S, Kabadurmus O, Cevikcan E, Satoglu SI, Durmusoglu MB (2019) A simulation-based methodology for the analysis of the effect of lean tools on energy efficiency: an application in power distribution industry. J Clean Prod 211:895–908.
[7] R. J. Collier, G. E. Dahl, and M. J. VanBaale, "Major Advances Associated with Environmental Effects on Dairy Cattle," Journal of Dairy Science, vol. 89, no. 4, pp. 1244–1253, Apr. 2006, doi: https://doi.org/10.3168/jds.S0022-0302(06)72193-2. Available: https://www.sciencedirect.com/science/article/pii/S0022030206721932

AI-based techniques play a crucial role in accelerating progress in renewable energy generation. By leveraging machine learning algorithms to analyse diverse data—such as precipitation patterns, solar radiation, wind speed, and energy demand—these systems can significantly enhance the efficiency and optimization of solar panels and wind turbines.

AI-scaled models offer a form of advanced intelligence that helps decode the complexities of extreme weather events, ocean currents, and carbon cycle dynamics. This enables scientists to make highly informed predictions and insights about changes in the Earth's climate system.

At the same time, AI-enhanced climate models are proving valuable in improving the accuracy of future climate forecasts. Machine learning algorithms can fine-tune existing models to deliver more precise projections based on different greenhouse gas emission scenarios.

The integration of machine learning into climate models is particularly significant for assessing climate risks and vulnerabilities. These algorithms can process global climate data and combine it with socioeconomic conditions, infrastructure weaknesses, and ecosystem dynamics to pinpoint regions most at risk from climate impacts. This, in turn, helps prioritize adaptation and resilience-building efforts more effectively.

In the energy sector, the implementation of artificial intelligence can heighten the efficiency of energy utilization by predicting energy demand, optimizing energy production and consumption, and realizing intelligent control, thus curtailing energy costs, lessening environmental pollution, and fostering sustainable development.[8] Artificial intelligence has recently revolutionized the energy sector, which has emerged as a revolutionary technological tool offering novel opportunities and challenges for enhancing energy efficiency and accomplishing sustainable development.[9]

V. CARBON CAPTURE AND LONG-TERM CONTAINMENT

Artificial Intelligence (AI) is becoming an essential enabler in advancing carbon capture and long-term storage (CCS) technologies, which are critical in achieving global climate targets. AI contributes across multiple stages of the CCS value chain—from site selection and operational optimization to monitoring and risk assessment—enhancing both efficiency and safety. Carbon sequestration and storage are pivotal elements of climate change mitigation strategies.[10] Artificial intelligence can also expedite the development of novel and ingenious carbon sequestration approaches, such as mineral carbonation, which converts carbon dioxide into stable minerals.[11] Artificial Intelligence (AI) is playing a growing and important role in improving how we capture and safely store carbon dioxide (CO_2)—a major step in fighting climate change. This process, known as carbon capture and storage (CCS), involves trapping CO_2 before it escapes into the atmosphere and then storing it deep underground where it can't contribute to global warming.

AI helps at every stage of this process. For example, it can quickly analyse huge amounts of data to find the best places to store CO_2, such as old oil fields or deep underground rock formations. AI can also make sure the carbon capture equipment works as efficiently as possible by reducing energy use and making real-time adjustments to operations.

Once the carbon is stored, it's important to keep a close eye on it to make sure it stays safely underground. AI systems can monitor the storage sites by using sensors and satellite data to detect any signs of leaks or changes. This kind of early warning system helps protect both the environment and nearby communities.

AI is also helping scientists develop new and innovative ways to lock away carbon permanently. One exciting method is mineral carbonation, where CO_2 is turned into solid rock-like minerals through natural chemical reactions. This means the carbon is stored in a stable, solid form that won't escape back into the air. Today, CCS projects are storing almost 45 million tons of CO_2 every year, which is about the amount of CO_2 emissions created by 10 million passenger cars.[12]

In short, AI is making carbon capture and storage faster, safer, and more effective. It's helping us reduce greenhouse gases and move closer to our climate goals by using smart technology to solve one of the world's biggest problems.

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[8] Khalilpourazari S, Khalilpourazary S, Özyüksel Çiftçioğlu A, Weber G-W (2021) Designing energy-efficient high-precision multi-pass turning processes via robust optimization and artificial intelligence. J Intell Manuf 32:1621–1647.

[9] Ahmed QW, Garg S, Rai A, Ramachandran M, Jhanjhi NZ, Masud M, Baz M (2022a) AI-based resource allocation techniques in wireless sensor internet of things networks in energy efficiency with data optimization.

[10] Liu T, Chen L, Yang M, Sandanayake M, Miao P, Shi Y, Yap P-S (2022b) Sustainability considerations of green buildings: a detailed overview on current advancements and future considerations.

[11] Ding Z, Chen Z, Liu J, Evrendilek F, He Y, Xie W (2022) Co-com bustion, life-cycle circularity, and artificial intelligence-based multi-objective optimization of two plastics and textile dyeing 1 3 2552 Environmental Chemistry Letters (2023) 21:2525–2557 sludge. J Hazard Mater 426:128069.

[12] Howard J. Herzog, "Carbon Capture," *MIT Climate Portal*, Massachusetts Institute of Technology, January 20, 2023, available at: https://climate.mit.edu/explainers/carbon-capture.

VI. WEATHER FORECASTING

Observations are key to weather forecasting and climate monitoring. Traditionally, processing this data—through steps like quality checks, bias correction, and model integration—has been complex and resource-intensive. AI is making this process faster and more accurate. For example, AI-based tools combining satellite and rain gauge data now outperform older methods in estimating rainfall. Systems like MIIDAPS-AI use AI to merge data from multiple satellites, delivering better atmospheric analysis in a fraction of the time—developed by just two people in under ten months and running 100 times faster than traditional systems.[13] AI is also helping extract new insights. One study used deep learning with optical flow to detect early signs of storm formation, showing how AI can enhance existing weather systems by revealing previously unused information.

VII. LEGAL INNOVATIONS THROUGH AI INTEGRATION

Artificial Intelligence is transforming the legal landscape of environmental governance by introducing smarter, faster, and more adaptive regulatory tools. As climate challenges grow more complex, AI helps legal systems become more proactive and responsive in enforcing environmental norms and managing compliance.

A. AI-Enhanced Regulatory Enforcement

AI tools can continuously monitor emissions, land use changes, and waste management quickly using satellite imagery, sensors, and data analytics. This enables environmental regulators to detect violations more quickly and accurately—whether it's illegal deforestation, unauthorized industrial discharges, or urban encroachment on protected zones. These systems reduce human error and make enforcement more efficient and transparent.

B. Algorithmic Environmental Assessments

Traditional Environmental Impact Assessments (EIAs) are often slow, static, and based on limited data. AI can upgrade these assessments by dynamically modelling environmental outcomes based on predictive data. This allows for more precise forecasting of impacts, helping policymakers and developers make better, evidence-based decisions about new projects.

C. AI in Environmental Litigation

AI tools can support environmental lawyers, judges, and litigants by analyzing large volumes of legal texts, identifying patterns in case law, and predicting legal outcomes. For example, predictive analytics can help estimate the likelihood of success in climate litigation or synthesize scientific evidence to support legal arguments. This accelerates legal research and supports more informed, consistent decision-making.

VIII. DOCTRINAL AND INSTITUTIONAL CHALLENGES IN AI-DRIVEN ENVIRONMENTAL GOVERNANCE

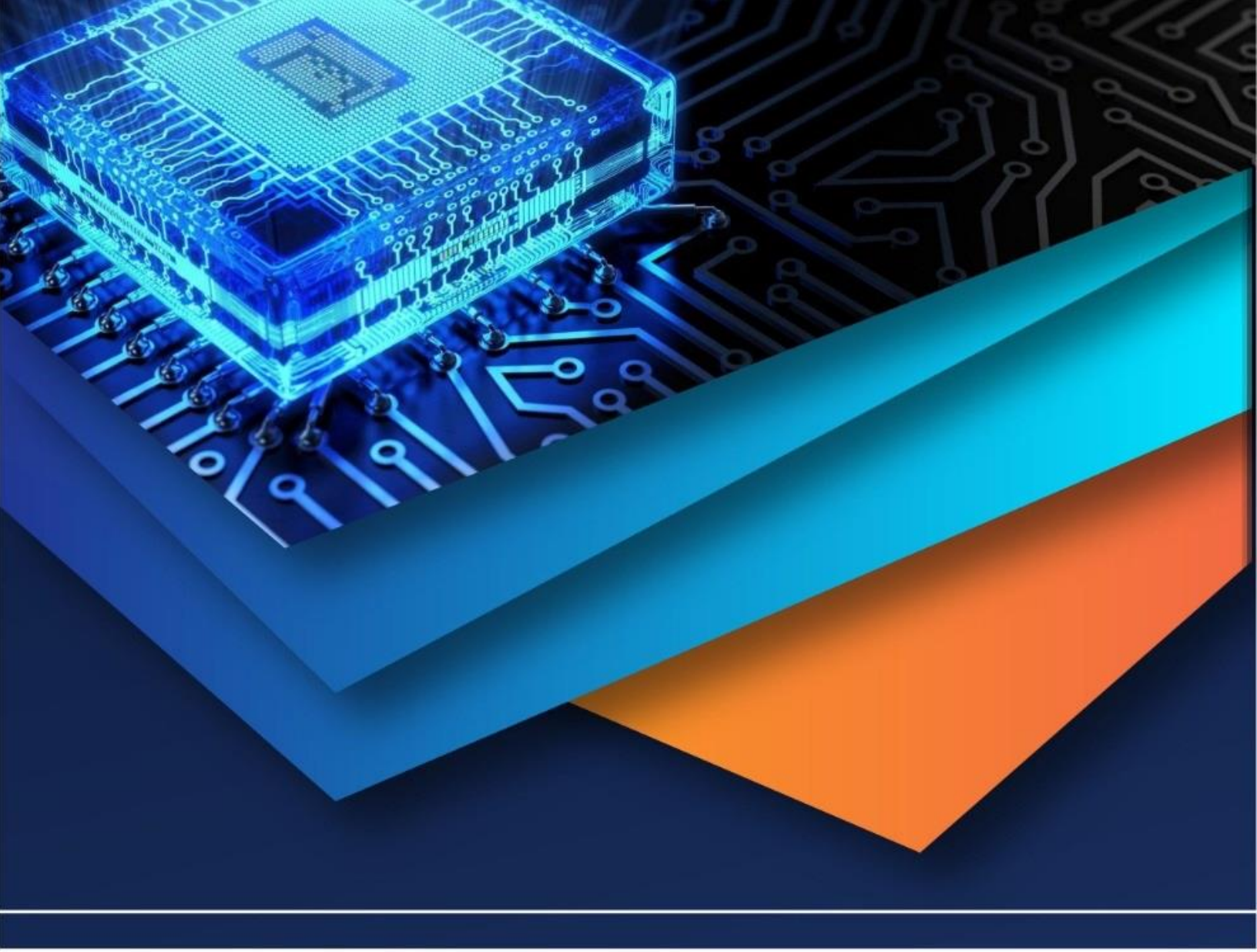
As artificial intelligence becomes more embedded in climate and environmental regulation, it brings with it a host of legal, ethical, and institutional challenges that test the boundaries of existing governance frameworks. Data availability, model validation, and computational ability are still among the major problems that need to be fully resolved and call for additional research and cooperation with the scientific communities.[14] The most important areas of AI relevance for ethics are the following: technical safety; transparency and privacy; beneficial use and capacity for good; malicious use and capacity for evil; bias in data, training sets; unemployment/lack of purpose and meaning; growing socio-economic inequality; environmental effects; automating ethics; moral deskilling and debility; AI consciousness, personhood, and 'robot rights'; AGI (artificial general intelligence) and superintelligence; dependency on AI; AI-powered addiction; isolation and loneliness; effects on the human spirit.[15] These tensions raise fundamental questions about responsibility, fairness, legitimacy, and the very nature of justice in the age of automation. One of the most pressing legal dilemmas is the issue of accountability. Training data for language models comes to a large extent from data freely available on the internet. It has the advantage that there is an enormous amount of data that can be used to train such models. A major disadvantage is that if huge unchecked datasets are used to train language models, then the system recycles and replicates data that

[13] Dueben, Peter D., et al. "Artificial Intelligence Revolutionizes Weather Forecast, Climate Monitoring and Decadal Prediction." *Remote Sensing*, vol. 13, no. 16, 2021, p. 3209. MDPI, available at: https://www.mdpi.com/2072-4292/13/16/3209.
[14] R. Lal, "Carbon Sequestration in Dryland Ecosystems," Environmental Management, vol. 33, no. 4, Dec. 2003, doi: https://doi.org/10.1007/s00267-003-9110-9.
[15] Green, B. P. (18 August 2020). Artificial intelligence and ethics: Sixteen challenges and opportunities. https://www.scu.edu/ethics/all-about-ethics/artificial-intelligence-and-ethics-sixteen-challenges-and-opportunities/

may be biased, unethical or flawed, thus amplifying them.[16] When AI systems used in environmental regulation or decision-making make errors or produce harmful outcomes, it's often unclear who should be held responsible—the developers, the users, or the agencies that rely on the technology. This “legal personhood” problem challenges traditional doctrines of liability and administrative accountability. There is also a delicate balance between using AI to enhance regulatory capacity and unintentionally allowing it to override democratic processes. Delegating complex decisions to machines risks eroding the rule of law if oversight and human judgment are sidelined. In environmental courts and agencies, this raises questions about institutional readiness, legitimacy, and public trust in automated systems. Ethical concerns further complicate this landscape. The use of surveillance technologies and data collection for environmental purposes can infringe on privacy rights and raise fears of overreach. Moreover, algorithmic bias can creep into decisions about how climate resources—such as funding, adaptation aid, or disaster relief—are allocated, potentially reinforcing existing inequalities. These issues are deeply connected to broader questions of justice and rights. As AI becomes a tool for managing environmental risks, it’s vital to ask who benefits from this shift. Communities with limited digital infrastructure may be excluded from AI-enabled services, widening the digital divide. Similarly, the increasing use of machine reasoning in nature-related decision-making could conflict with emerging legal movements that seek to recognize the rights of ecosystems and non-human entities.

IX. CONCLUSION

The incorporation of AI into environmental governance marks a significant evolution in how societies confront climate change and ecological challenges. While AI technologies offer powerful tools for monitoring, decision-making, and enforcement, they also unsettle established legal and ethical norms. The issues of accountability, transparency, fairness, and institutional legitimacy cannot be overlooked as governance systems adapt to these new realities. Addressing these challenges requires more than technical fixes; it demands a comprehensive rethinking of legal frameworks to ensure they remain robust and just in the face of automation. Clear lines of responsibility must be established so that when AI systems err or cause harm, affected parties can seek redress and hold the right actors accountable. Procedural safeguards need to be strengthened to ensure that decisions influenced or made by AI remain transparent and open to meaningful scrutiny, preserving fundamental rights such as due process and participation. Ethically, the deployment of AI in environmental contexts must be guided by principles of equity and inclusion. Policymakers should actively work to prevent algorithmic biases from exacerbating existing social inequalities and address the digital divide that threatens to leave vulnerable communities behind. Recognizing the rights of nature alongside technological advancements also calls for innovative legal thinking that respects ecological values and balances them against machine-driven objectivity.



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