ARTIFICIAL INTELLIGENCE AND CLIMATE CHANGE: LEGAL CHALLENGES AND OPPORTUNITIES FOR OCEAN PROTECTION

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SUMMARY: 1.- Introduction; 2.- AI's Potential for Climate Mitigation and Adaptation; 3.- AI-Driven Climate Action: Key Legal Challenges; 4.- AI's Role in Ocean Protection: A Climate Mitigation Approach; 5.- Conclusions and Future Perspectives.

1.- **Introduction.**

The Intergovernmental Panel on Climate Change (IPCC) has consistently stressed the urgency of implementing large-scale measures to address human-induced climate change[1]. A key factor of modern climate action is its strong connection to sustainable development – a concept that, while not new, has taken on renewed significance[2]. From a legal perspective, sustainability is embedded in various international instruments, including treaties[3], resolutions of international organizations[4], and rulings from international courts and tribunals[5]. More recently, the United Nations' 2030 Agenda for Sustainable Development – commonly known as the Sustainable Development Goals (SDGs) – aims to tackle a wide range of global issues, including poverty, gender inequality, climate change, and environmental degradation[6]. Among its objectives are the promotion of sustainable land use, responsible forest management, desertification prevention, and biodiversity conservation.

Artificial intelligence (AI) represents a promising avenue for accelerating progress toward these goals. The increasing availability of data – collected through satellites, mobile technology, and environmental sensors – provides unprecedented insights into the state of the planet. AI-powered solutions can enhance climate resilience by improving weather forecasts, predicting natural disasters, and optimizing environmental monitoring. They are also instrumental in tackling illegal activities such as deforestation, water pollution, and illegal fishing, while also helping to manage air quality and agricultural sustainability[7]. By leveraging AI, the global community can take more effective, data-driven steps toward achieving sustainable development and mitigating climate change.

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[1] V. Masson-Delmotte and others (curr.), *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* (2018), www.ipcc.ch.

[2] See J.E. Viñuales, *Sustainable Development*, in L. Rajamani and J. Peel (curr.), *The Oxford Handbook of International Environmental Law*, 2nd ed., Oxford 2021, 292; United Nations General Assembly (UNGA), *Political declaration of the high-level political forum on sustainable development convened under the auspices of the General Assembly* (9/9/2019) A/HLPF/2019/L.1.

[3] United Nations Framework Convention on Climate Change (UNFCC) (9/5/1992) 1771 UNTS 107, art. 3; Kyoto Protocol (11/12/1997) 2303 UNTS 162, art. 2; Paris Agreement (12/12/2015) 3156 UNTS 79, art. 2.

[4] See e.g., UNGA, *United Nations Millennium Declaration*, (18/9/2000) A/RES/55/2; Id., *Annex: The Future We Want*, (27/7/2012) A/RES/66/288.

[5] International Court of Justice (ICJ), *Case Concerning the Gabčíkovo-Nagymaros Project (Hungary/Slovakia)*, 25/9/1997, I.C.J. Reports 1997, para. 140; Permanent Court of Arbitration (PCA), *Iron Rhine Arbitration (Belgium/Netherlands)*, 24/5/2005, no. 2003-02, para. 222.

[6] UNGA, *Transforming Our World: The 2030 Agenda for Sustainable Development* (21/10/2015) A/RES/70/1, 14.

[7] M. Chui and others (curr.), *Notes From the AI Frontier: Applying AI for Social Good*, McKinsey Global Institute 2018, www.mckinsey.com, 24ss.

However, the use of these technologies also brings significant legal and ethical challenges that require careful consideration. As a result, on one hand, AI can significantly improve our understanding of global warming and play a key role in the range of solutions needed to address this crisis. By enabling more sustainable, efficient, and environmentally friendly approaches, AI has the potential to enhance climate action. On the other hand, its integration into environmental and policy frameworks also raises serious concerns regarding algorithmic bias, discrimination, and lack of transparency in decision-making processes.

This study analyzes the potential of artificial intelligence as a constructive tool in addressing climate change. Given that AI is a rapidly evolving technology, the article examines its benefits in advancing climate action, as outlined in the United Nations Sustainable Development Goals (SDGs), particularly through mechanisms that enhance environmental monitoring and management. The analysis begins by discussing how AI can contribute to environmental protection, followed by an examination of key legal challenges that may arise when integrating AI into climate-related initiatives. The study then highlights a specific application of AI in maritime monitoring, focusing on its role in promoting sustainable resource management and mitigating environmental impacts. Finally, the paper argues that international environmental law should adapt to the continuous advancements in AI technologies – both to maximize their full potential in addressing climate change and to mitigate any associated risks.

2.- **AI's Potential for Climate Mitigation and Adaptation.**

For decades, the international community has prioritized initiatives aimed at promoting sustainable development across various sectors. Sustainable development can be understood as a process that inherently integrates environmental protection, ensuring that economic and social progress aligns with a state's environmental treaty obligations or, at a minimum, with the fundamental principles of customary international environmental law[8].

Currently, a significant step toward sustainable development was the adoption of the 2030 Agenda for Sustainable Development by UN Member States at the 2015 summit. Consisting of 17 goals, it aims to promote a comprehensive and integrated approach to global progress. Goal 13 underscores the urgent need to take action against climate change and its impacts. This goal is closely linked to other SDGs, including Goal 14, which focuses on the conservation and sustainable use of oceans, seas, and marine resources, and Goal 15, which calls for the protection, restoration, and sustainable management of terrestrial ecosystems, emphasizing the importance of forest conservation, combating desertification, reversing land degradation, and halting biodiversity loss. In particular, the 2030 Agenda outlines three key objectives related to climate action. First, it calls for strengthening the resilience and adaptive capacity of all countries to climate-related hazards and natural disasters. Second, it emphasizes the need to integrate climate change measures into national policies, strategies, and planning efforts. Third, it highlights the importance of improving education, raising awareness, and enhancing both human and institutional capacity in areas such as climate change mitigation,

[8] G. Le Moli, P.M. Dupuy, J.E. Viñuales, *Customary International Law and the Environment*, in L. Rajamani, J. Peel (curr.), *The Oxford Handbook of International Environmental Law*, 2nd ed., Oxford 2021, 385-401. See also ICJ, *Legality of the Threat or Use of Nuclear Weapons, Advisory Opinion*, I.C.J. Reports 1996 (I), 226, para. 29: "[…] The existence of the general obligation of states to ensure that activities within their jurisdiction and control respect the environment of other states or of areas beyond national control is now part of the corpus of international law relating to the environment".

adaptation, impact reduction, and early warning[9]. Together, these objectives reflect the need of a comprehensive and coordinated approach to addressing the global climate crisis.

The close link between these goals underlines the expanded potential of artificial intelligence in contributing to their achievement. The 2022 IPCC Report further reinforces this perspective, noting that digital technologies, including AI, can play a significant role in mitigating climate change and advancing several Sustainable Development Goals[10]. One of the key advantages of using AI in environmental law is its ability to significantly improve environmental monitoring. By processing large volumes of data from diverse sources – such as satellites, ground sensors, and even social media – AI can deliver real-time insights into environmental conditions. These insights are crucial for detecting and responding quickly to threats like natural disasters, pollution events, or risks to wildlife[11].

AI can also play a crucial role in supporting both climate adaptation and mitigation strategies by offering data-driven insights into the effects of climate change and the effectiveness of various responses. For instance, AI-powered climate models can simulate multiple scenarios to forecast potential impacts on ecosystems, infrastructure, and human communities[12]. These projections help inform the planning and evaluation of adaptation measures such as sea walls, green infrastructure, and emergency preparedness strategies. On the mitigation side, AI can assist in areas like renewable energy deployment, carbon capture, and waste reduction by analyzing data on energy use, emissions, and waste patterns – ultimately helping to identify and recommend the most effective interventions[13].

The potential of these technologies is further emphasized in Article 4(5) of the United Nations Framework Convention on Climate Change (UNFCCC) which requires Parties to take all feasible measures to promote, support, and finance the development and transfer of technology as a means to achieve their climate mitigation objectives[14]. For example, AI is already being used around the world to address environmental challenges: in Japan, it helps issue disaster alerts for tsunami-related flooding[15]; in Brazil, it monitors deforestation in the Amazon[16]; and in China, it plays a key role in the development of smart cities[17].

Despite its many benefits, the training of AI systems comes with significant environmental costs, largely due to the high energy consumption and resulting carbon footprint of modern tensor processing hardware. This concern is highlighted in the European Parliament's Special Committee

[9] UNGA, *Transforming Our World* cit. 23.

[10] H.-O. Pörtner and others (curr.), *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge 2022.

[11] R. Cho, *Artificial Intelligence – A Game Changer for Climate Change and the Environment*, Columbia Climate School (2018), www.news.climate.columbia.edu.

[12] N. Chaudhary, *AI and the Fight Against Climate Change: Opportunities and Challenges for Environmental Law*, in *International Journal of Law Management & Humanities* 6 (2023) 390ff.

[13] A. Mishra, A. Pandey, S. Mohanty, *Assessing Climate Change through Artificial Intelligence*, in S. Mohanty, P. Nanjundan, T. Kar (curr.), *Artificial Intelligence in Forecasting*, Boca Raton 2024, 130ff.

[14] See above n. 3.

[15] F. Imamura, *Fujitsu Leverages World's Fastest Supercomputer and AI to Predict Tsunami Flooding*, Tohoku University (2021), www.tohoku.ac.jp.

[16] A. Erthal Abdenur, *How Can Artificial Intelligence Help Curb Deforestation in the Amazon?*, IPI Global Observatory (2020), www.theglobalobservatory.org.

[17] A. Hsu and others, *Chinese Cities As Digital Environmental Governance Innovators: Evidence From Subnational Low-Carbon Plans*, in *Environment and Planning B: Urban Analytics and City Science* 51 (2024) 572ff.

on Artificial Intelligence in a Digital Age (AIDA)[18]. The study examines both the positive and negative environmental impacts of AI in the context of the Green Deal's objectives[19], which are closely aligned with the UN Sustainable Development Goals. However, most international initiatives on AI still fall short in addressing the environmental aspects of sustainable development. As a result, there is a pressing need for environmental policy and research to more thoroughly evaluate the systemic effects of AI technologies.

3.- **AI-Driven Climate Action: Key Legal Challenges.**

Climate change poses a serious threat to the planet, and artificial intelligence is increasingly being utilized as a tool to address its complex challenges. While the regulation of AI is still in its early stages, in 2019, the Organization for Economic Co-operation and Development (OECD) has taken a significant step by introducing a set of guiding principles, reflecting a growing international consensus on the responsible development and use of AI[20]. According to the OECD, AI should serve both people and the planet by fostering inclusive growth, supporting sustainable development, addressing climate change, and enhancing overall prosperity. To contribute to a fair and just society, AI systems must respect the rule of law, human rights, democratic values, and diversity, and they should be equipped with safeguards that allow for human oversight when necessary. Moreover, AI must remain safe and reliable throughout its entire life cycle, with continuous monitoring and management of potential risks.

Subsequently, in November 2021, the Global Partnership on Artificial Intelligence (GPAI) published a report including various recommendations aimed at guiding governments in two key areas: supporting the effective use of artificial intelligence to address climate-related challenges, and managing the environmental risks that AI itself may pose[21]. The report, presented at the 2021 UN Climate Change Conference in Glasgow, offers a comprehensive roadmap for integrating AI into climate policy while ensuring that its development remains aligned with sustainability goals. It urges governments to take a series of coordinated actions to harness the potential of artificial intelligence in addressing climate change. It emphasizes the need to strengthen data ecosystems in key sectors essential to the climate transition – such as energy and transport – by promoting tools like digital twins[22]. Additionally, the report calls for increased investment in research, innovation, and deployment, supported by targeted funding, robust infrastructure, and improved market structures. It also stresses the importance of integrating climate considerations into national AI strategies to ensure that the overall development of artificial intelligence aligns with environmental goals. Finally, the

[18] P. Gailhofer and others, *The role of Artificial Intelligence in the European Green Deal, Study for the Special Committee on Artificial Intelligence in a Digital Age (AIDA)*, Policy Department for Economic, Scientific and Quality of Life Policies, European Parliament (2021), www.europarl.europa.eu.

[19] European Commission, *Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions: The European Green Deal*, 11/12/2019, COM (2019) 640.

[20] Organization for Economic Co-operation and Development (OECD), *Recommendation of the Council on Artificial Intelligence*, 22/05/2019, OECD/LEGAL/0449.

[21] GPAI in collaboration with Climate Change AI and the Centre for AI & Climate, *Climate Change & AI: Recommendations for Government* (2021), www.gpai.ai.

[22] A digital twin is a virtual representation of a physical object, system, process, or even a person, embedded within a digital model of its real-world environment. By simulating real-world scenarios and predicting possible outcomes, digital twins enable organizations to test strategies, optimize performance, and make more informed, data-driven decisions. See M.R. Abayadeera, G.U. Ganegoda, *Digital Twin Technology: A Comprehensive Review*, in *International Journal of Scientific Research & Engineering Trends* 10 (2024) 1485ff.

report highlights the value of enhanced international collaboration and capacity building to support the effective development and governance of AI-driven climate solutions.

In addition, in 2021, UNESCO adopted the Recommendation on the Ethics of Artificial Intelligence which seeks to establish global standards for the regulation of AI across United Nations Member States[23]. Its primary goal is to offer a universal framework of values, principles, and actions to guide governments in developing legislation, policies, and other regulatory tools related to AI, ensuring alignment with international law. The Recommendation also outlines a set of key principles that serve as guidance for the design and development of artificial intelligence systems. These include safety and security, fairness and non-discrimination, sustainability, human oversight and control, transparency and explainability, as well as responsibility and accountability[24]. Importantly, the document also incorporates environmental considerations, encouraging ecosystem-friendly AI design. In particular, UNESCO recommends reducing the carbon footprint of AI systems, taking into account environmental risk factors, and avoiding the unsustainable exploitation of natural resources[25]. This framework represents an important step toward building international legal and ethical standards for the use of AI in tackling global challenges such as climate change. It is largely composed of soft law, which, although not legally binding, plays an important role in shaping norms and guiding responsible AI use. In light of the current lack of binding international provisions on artificial intelligence – both broadly and in relation to climate change – these recommendations serve as essential tools for addressing legal gaps and informing future regulatory developments. They serve to encourage states active participation in international efforts to address the complex and far-reaching challenges posed by artificial intelligence.

Soft law instruments can exert significant influence over state practice by encouraging the adoption of shared standards, and they may eventually lead to the development of binding norms – either through the conclusion of formal treaties or by evolving into customary international law. In the field of environmental law, a major turning point was the 1972 Stockholm Declaration, which introduced 26 principles that laid the foundation for global environmental awareness and protection[26]. Two decades later, the Rio Declaration built upon this foundation by articulating key principles that would serve as the basis for future binding legal frameworks, including the principle of sustainable development, the precautionary principle, and the prohibition of transboundary pollution[27]. For instance, the precautionary principle is now explicitly included in international treaties – such as the UNFCCC[28], the Convention on the Protection of the Marine Environment of the Baltic Sea Area[29], and the Montreal Protocol on Substances that Deplete the Ozone Layer[30] – and most scholars agree on the customary nature of the principle on the prohibition of transboundary pollution[31]. Therefore,

[23] UNESCO, *Recommendation on the Ethics of Artificial Intelligence*, 23/11/2021, SHS/BIO/PI/2021/1.
[24] Id., *Recommendation* cit. par. 25-47.
[25] Id., *Recommendation* cit. par. 84-86.
[26] Declaration of the United Nations Conference on the Human Environment (Stockholm, 16/6/1972), UNGA Resolutions 2994/XXVII, 2995/UVII and 2996/XXII of 15 December 1972.
[27] Rio Declaration on Environment and Development (14/6/1992) UN Doc. A/CONF.151/26 (vol. I), 31 ILM 874 (1992).
[28] UNFCCC, art. 3.
[29] Convention on the Protection of the Marine Environment of the Baltic Sea Area (22/3/1974) 1507 UNTS 166.
[30] Montreal Protocol on Substances that Deplete the Ozone Layer (16/9/1987) 1522 UNTS 3, Preamble.
[31] P. Sands and others (curr.), *Principles of International Environmental Law*, 4th ed., Cambridge 2018; A. Boyle, C. Redgwell, *Birnie, Boyle, and Redgwell's International Law and the Environment*, 4th ed., Oxford 2021. See also *Trail smelter case (United States, Canada)*, 16/4/1938 and 11/3/1941, Reports of International Arbitral Awards Vol. III 1905-1982; Permanent Court of Arbitration, *Iron Rhine Arbitration (Belgium/Netherlands)*, 24/5/2005, Case No. 2003-02.

the measures adopted by States in the context of climate action must be guided by existing customary norms and principles of international environmental law. These include also the no-harm principle, the requirement for environmental impact assessments and the duty to protect and conserve the environment and natural resources[32].

There are several multilateral treaties that aim to combat climate change and its consequences. These include the UNFCCC, the Kyoto Protocol[33], and the Paris Agreement. While these treaties do not directly regulate artificial intelligence, the latter includes some provisions that may indirectly influence how AI is used in climate action. In particular, the Paris Agreement includes provisions that can shape how countries develop, adjust, or enhance their domestic policies to meet its requirements. For instance, each Party is obliged to maintain a Nationally Determined Contribution (NDC), which sets out its own climate mitigation targets. While the content of these targets is self-defined, countries are legally required to implement national measures aimed at fulfilling the commitments outlined in their NDCs[34]. These measures may include the integration of AI technologies. In addition, Article 10(1) of the Paris Agreement emphasizes the shared long-term vision of State Parties on the importance of fully realizing the development and transfer of technology to enhance climate resilience and reduce greenhouse gas emissions. This Article could be interpreted as implicitly discouraging the use of AI systems that contribute to climate harm.

However, none of these agreements specifically addresses the potential legal and ethical challenges arising from the use of emerging technologies, such as artificial intelligence, in climate change action. One of the key challenges in applying AI to environmental law is the question of accountability[35]. AI systems are often highly complex and operate as "black boxes", making it difficult to trace how decisions are made or to identify who is ultimately responsible for their outcomes. This becomes particularly problematic when AI systems cause harm to the environment or human health – for example, if an AI system misclassifies pollutants, leading to environmental damage. To effectively address this issue, environmental law should establish clear frameworks for accountability and liability.

Closely related to accountability is the challenge of transparency[36]. AI decision-making processes are often inaccessible or not easily understood. This lack of transparency is particularly concerning when AI is used in contexts that have direct environmental implications, such as conducting environmental impact assessments. To mitigate this, environmental law should require that AI systems used in regulatory or decision-making contexts be transparent and explainable. Their functioning should be subject to rigorous oversight, and mechanisms must be in place to allow public or institutional scrutiny of how decisions are made.

A third major challenge in the application of AI to environmental law is the risk of bias and discrimination[37]. AI systems rely heavily on the data they are trained on, and if this data contains

[32] L. Bakošová, *Climate Action Through Artificial Intelligence: International Legal Perspective*, in *Studia Iuridica Cassoviensia* 10 (2022) 13.
[33] See above n. 3.
[34] Paris Agreement, art. 4(2).
[35] R. Rayfuse, *Public International Law and the Regulation of Emerging Technologies*, in R. Brownsword, E. Scotford, K. Yeung (curr.), *The Oxford Handbook of Law, Regulation and Technology*, Oxford 2017.
[36] L. Vihul, *International Legal Regulation of Autonomous Technologies*, Centre for International Governance Innovation (2020), www.cigionline.org.
[37] J. Cowls and others, *The AI Gambit: Leveraging Artificial Intelligence to Combat Climate Change: Opportunities, Challenges, and Recommendations*, in *AI & Society* 38 (2023) 289.

historical or systemic biases, those biases can be embedded in the system's outputs. As a result, AI-driven decisions may unintentionally reinforce existing environmental inequalities – such as disproportionately affecting marginalized communities or neglecting vulnerable ecosystems. This presents a serious concern for environmental justice, as it can lead to unfair or unequal environmental outcomes. To mitigate this risk, environmental law should promote the use of diverse, high-quality, and representative datasets when training AI systems. Moreover, AI decision-making processes should be designed with safeguards to detect and address potential biases, ensuring that the deployment of AI supports fairness and equity in environmental governance.

Building on the instruments previously discussed, there is a growing need for the adoption of a dedicated international treaty to ensure the responsible and trustworthy use of artificial intelligence in the field of climate action[38]. Such a treaty could establish uniform standards for data management, human oversight, operational limitations, and the prevention of algorithmic bias. Crucially, any such framework should include rigorous impact assessments that evaluate the ethical, legal, and societal implications of AI applications – particularly in terms of transparency, fairness, and accountability – to ensure that AI contributes positively and equitably to climate mitigation and adaptation efforts.

4.- **AI's Role in Ocean Protection: A Climate Mitigation Approach.**

Artificial intelligence offers significant potential to accelerate progress toward many of the United Nations Sustainable Development Goals (SDGs). A particularly innovative example is the concept of AI-enabled Mobile Marine Protected Areas (MMPAs) – a new, digitally-driven approach to earth system governance. These dynamic conservation zones have movable boundaries that shift in real time as endangered marine species migrate, offering a flexible and adaptive method of protecting biodiversity in alignment with SDG 14, which focuses on the conservation and sustainable use of ocean resources.

The effectiveness of MMPAs relies on a combination of advanced digital technologies and AI-powered analytics. Data is collected from a range of sources, including nanosatellites, drones, environmental sensor networks, digital bioacoustics, marine tags, and deep-sea unmanned vehicles (UAVs)[39]. This data is then processed using tools such as machine learning algorithms, computer vision, and ecological informatics, enabling real-time monitoring and management of marine ecosystems. This emerging model represents a cutting-edge example of how AI can support responsive, data-driven ocean governance[40]. MMPAs serve as a compelling case study for the future of environmental governance in the digital era. While they showcase the potential of AI-driven technologies to transform how we monitor and manage ecosystems, they also raise important

[38] Vihul, *International Legal Regulation* cit.

[39] A new Mobile Marine Protected Area (MMPA) has been established in the Great Australian Bight to protect endangered southern bluefin tuna. To address overfishing and bycatch, scientists and fisheries managers have implemented a real-time management system using satellite-linked fish tags, ocean temperature data, and habitat preference models. These inputs generate predictive maps that identify tuna hotspots with high precision and forecast their locations up to 60 days in advance. This allows fishers to anticipate and avoid designated "no-go" zones, improving conservation while supporting sustainable fishing practices. See J.R. Hartog, and A.J. Hobday, *Case study 8: Dynamic Spatial Management in an Australian Tuna Fishery*, in T.E. Lovejoy and H. Hannah (curr.), *Biodiversity and Climate Change,* New Haven 2019, 263-265.

[40] K. Bakker, *Smart Oceans: Artificial intelligence and marine protected area governance*, in *Earth System Governance* 13 (2022) 1ff.

questions about the broader implications of integrating artificial intelligence into earth system governance.

On 19 June 2023, the Agreement under the United Nations Convention on the Law of the Sea on the Conservation and Sustainable Use of Marine Biological Diversity of Areas Beyond National Jurisdiction (BBNJ Agreement) was formally adopted by the Intergovernmental Conference convened under the auspices of the United Nations[41]. Nearly two decades in the making, the BBNJ Agreement establishes a global framework for the protection of marine biodiversity in areas beyond national jurisdiction (ABNJ). As it seeks to protect fragile ecosystems in a context of accelerating climate change and technological innovation, the agreement necessarily intersects with the expanding role of artificial intelligence (AI) in environmental monitoring, data processing, and marine policy enforcement[42].

Under the United Nations Convention on the Law of the Sea (UNCLOS) and the BBNJ Agreement, sates are expected to cooperate in the conservation and sustainable use of marine biodiversity. MMPAs are especially relevant to current discussions on managing biodiversity beyond national jurisdiction, however there is no clear legal framework specifically addressing new technologies deployment in marine governance. The BBNJ Agreement does not contain explicit provision on AI or big data. Its references to technology transfer are focused more on capacity-building for developing countries than on the ethical use of advanced digital systems[43].

Without specific international norms governing AI in environmental governance, the risk is that powerful tools may be deployed in ways that exceed legal scrutiny, potentially undermining the very conservation goals the BBNJ Agreement aims to advance. In this context, the precautionary principle could provide an essential normative guide. Indeed, it mandates that states take preventive action in the face of scientific uncertainty to avoid serious or irreversible environmental harm[44].

The BBNJ Agreement references ecosystem-based and precautionary approaches, particularly in the creation of area-based management tools such as marine protected areas (MPAs)[45]. However, the growing use of AI-powered monitoring systems raises new questions about how the precautionary principle should be interpreted and operationalized in light of technological uncertainty. Potential harms arising from data misclassification, model inaccuracies, or unforeseen ecological impacts – including carbon footprint, energy use, and e-waste generation from automated systems – cannot be ruled out. In this context, the precautionary principle requires that states not only consider the benefits of deploying AI in high seas governance but also anticipate its risks and act preventively when those risks are not yet fully understood. Furthermore, the application of the precautionary principle to AI systems must go beyond ecological considerations to include societal and ethical dimensions. Developing countries have emphasized these concerns during BBNJ negotiations, advocating for

[41] Agreement under the United Nations Convention on the Law of the Sea on the Conservation and Sustainable Use of Marine Biological Diversity of Areas beyond National Jurisdiction (BBNJ Agreement) (19/6/2023, not yet in force) C.N.203.2023.TREATIES-XXI.10.

[42] K. Lucey, *Marine Protected and Conserved Areas: Beneficial Uses of Artificial Intelligence*, in *Catholic University Journal of Law and Technology* 32 (2024) 131ff.

[43] BBNJ Agreement, arts. 40-46.

[44] J.F. Pinto-Bazurco, *The Precautionary Principle*, Earth Negotiations Bulletin, 2020, www.iisd.org.

[45] BBNJ Agreement, art. 7.

inclusive access to data and technology transfer[46], which are essential to implementing a precautionary and equitable model of ocean governance[47].

As environmental governance enters the digital age, the challenge is not simply to adopt new technologies, but to ensure they are embedded in systems of law that are transparent, accountable, and ecologically just. Therefore, while the BBNJ Agreement represents progress in including environmental principles into high seas governance, its effectiveness will depend on how well it integrates and applies the precautionary principle in regulating rapidly advancing technologies like AI. In the absence of specific treaty provisions, States should rely on this principle as a substantive standard guiding the design, deployment, and oversight of AI systems in the marine environment.

Finally, to align the BBNJ Agreement with both the opportunities and risks of AI, some recommendations should be taken into consideration. First, international binding legal standards for the deployment of AI technologies in the oceans should be integrated in marine governance. Second, impact assessments for AI-driven monitoring tools should be required under the BBNJ environmental assessment procedures. Third, the precautionary principle should be embedded into AI-related decision-making, especially where ecological data is incomplete or uncertain.

5.- **Conclusions and Future Perspectives.**

The analysis conducted throughout this study highlights the transformative potential of artificial intelligence in advancing climate action under international environmental law. However, this potential is accompanied by significant legal and ethical challenges that the current international legal framework is only beginning to address. While the integration of AI into environmental governance offers innovative pathways for monitoring, mitigation, and adaptation, the lack of binding international standards, particularly in the context of ocean protection and climate regulation, leaves a substantial gap.

A critical barrier to legal and policy coherence lies in the difficulty of reaching consensus at the multilateral level. Deep divergences in technological capacity, political priorities, and regulatory approaches continue to divide the Global North and South. This is especially evident in the context of technology transfer, data access, and capacity-building – dimensions that are essential for ensuring equitable participation in AI-driven climate governance. Without meaningful inclusion of developing countries in both the design and deployment of technological tools, there is a risk that AI may reinforce existing asymmetries rather than contribute to a more sustainable global order.

Furthermore, the effectiveness of current legal instruments – most of which rely on soft law mechanisms – raises questions about enforceability and long-term impact. While soft law can influence state behavior and contribute to the formation of customary norms, it often lacks the institutional force needed to ensure accountability, especially in a rapidly evolving technological landscape. Bridging this normative gap will require the development of an inclusive, adaptive, and enforceable legal mechanisms that keep pace with technological innovation while remaining grounded in the values of environmental protection and international solidarity. The challenge is not

[46] BBNJ Agreement, arts. 51-52.

[47] R. Derrig and others, *Protecting the Ocean in the Contemporary International Order: Capacity-Building and Technology Transfer from the Stockholm Declaration to the BBNJ Agreement*, in *The International Journal of Marine and Coastal Law* 39 (2024) 571ff.

merely to keep up with innovation, but to ensure that the digital tools we deploy today do not become the sources of exclusion, inequity, or ecological harm tomorrow.

Abstract.- Il contributo analizza il potenziale dell'intelligenza artificiale (IA) come strumento per l'azione climatica e la protezione degli oceani, con particolare attenzione alle implicazioni giuridiche, etiche e di governance. Dopo una ricognizione delle tecnologie digitali avanzate – dai satelliti alle reti di sensori e alle analisi bioacustiche – si esamina come l'IA possa rafforzare il monitoraggio ambientale, migliorare le previsioni climatiche e sostenere strategie di gestione adattativa dei rischi. Un'attenzione specifica è rivolta al modello innovativo delle "Mobile Marine Protected Areas" (MMPAs), che rappresenta un esempio di governance dinamica abilitata dall'IA. Lo studio valuta criticamente i rischi associati, tra cui opacità algoritmica, responsabilità giuridica, "bias" nei dati e impatti ambientali della computazione intensiva. Analizzando il quadro normativo internazionale esistente, vengono individuate lacune e asimmetrie di accesso tra Stati. Per colmare tali vuoti, l'articolo propone misure quali standard vincolanti per l'uso dell'IA negli oceani, valutazioni d'impatto etiche e ambientali obbligatorie, integrazione del principio di precauzione e programmi di trasferimento tecnologico e "capacity-building". Si conclude che il diritto internazionale dell'ambiente debba evolvere in maniera inclusiva ed efficace, così da massimizzare i benefici dell'IA, garantire equità ed evitare asimmetrie nell'accesso alle tecnologie, e prevenire danno ecologico.

This article explores the potential of artificial intelligence (AI) as a tool for climate action and ocean protection, with a focus on legal, ethical, and governance implications. It surveys advanced digital technologies – including satellites, sensor networks, and bioacoustic monitoring – and considers how AI can enhance environmental monitoring, improve climate forecasting, and support adaptive risk management. Particular emphasis is placed on Mobile Marine Protected Areas (MMPAs), an innovative model of AI-enabled dynamic governance for biodiversity conservation. The paper critically assesses attendant risks, such as algorithmic opacity, accountability issues, data bias, and the environmental footprint of intensive computation. By reviewing the current international legal framework, the study identifies regulatory gaps and inequalities in access to data and technology. It proposes policy responses including binding standards for AI deployed in ocean governance, mandatory ethical and environmental impact assessments, application of the precautionary principle, and measures for capacity-building and technology transfer. The article concludes that international environmental law must evolve in an inclusive and effective manner to harness AI's benefits, ensure equity and avoid asymmetries in access to technology, and prevent ecological harm.