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XAI and Sustainability: Unifying Regulatory Standards and Solutions for the Future of Environmental Management

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XAI and Sustainability: unifying regulatory standards and solutions for the future of environmental management

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Abstract: In this study, the integration of Explainable Artificial Intelligence (XAI) within environmental management is examined, with a focus on critical issues such as algorithmic transparency, public trust and regulatory compliance. As AI increasingly influences decisions in environmental governance, it is imperative that these decisions remain transparent, fair and accessible to all stakeholders to support equitable governance. Current XAI methodologies are analyzed for their potential to enhance understanding in areas such as climate prediction, biodiversity monitoring and sustainable resource management. The necessity for harmonized global standards is discussed, emphasizing the need for unified approaches to environmental and AI governance. Regulatory frameworks, including the EU's AI Act and GDPR, are evaluated to outline the legal implications and challenges of implementing XAI in a fragmented global landscape. Furthermore, a participatory, multidisciplinary approach is proposed to encourage public involvement in AI-driven environmental decisions, fostering transparency and social accountability. This study aims to provide insights for policymakers, corporations and international organizations to support the development of ethical and inclusive AI practices that advance sustainability while upholding public trust and fairness in environmental management.

1. Introduction

In recent years, the use of Artificial Intelligence (hereinafter, “AI”) in environmental management has grown significantly. With all the advancements in the digitalization of environmental data and the increasing use of tools such as the Internet of Things (hereinafter, “IoT”) and Big Data (hereinafter, “BD”), there is an unprecedented opportunity to improve ecosystem management and predict environmental changes. By enabling detailed analysis of large volumes of data and providing accurate predictions about patterns of environmental use and degradation, remote sensing, ecological system modeling and deep learning algorithms are some of the tools that are being widely used

in biodiversity monitoring, climate change prediction and natural resource use optimization (Reddy et al., 2021; Deep and Verma, 2024). Nevertheless, regardless of the undeniable potential of this entire technological framework, if it is not accompanied by responsible governance that takes into account equity and justice in the use of environmental commons, very few of its real benefits will be captured in a timely manner. Indeed, as the complexity of these technologies increases, the need to ensure that their decisions are transparent, accessible and fair also intensifies (Papadakis et al., 2024; Hacker, 2024). The literature has focused on the creation of accurate algorithmic models, but the discussion about their interpretation is an ongoing process; in the vast majority of cases, even if the algorithms deliver effective results for a given purpose, their complexity and particularities make it impossible for any individual, despite their status as an expert or layperson, to understand how these results are achieved. This gap between accuracy and interpretability is particularly worrying in environmental management, a field in which decisions directly impact entire communities and ecosystems. In this sense, the growing need to combine technical efficiency with transparency and explainability is now vastly recognized (Papadakis et al., 2024).

The field of Explainable Artificial Intelligence (hereinafter, “XAI”) has come to respond to this demand, promoting approaches that allow the interpretation of the results generated by complex models, without compromising predictive effectiveness (Barredo Arrieta et al., 2020): by providing greater transparency, its tools will allow automated decisions to be auditable and questionable, contributing to more ethical and inclusive governance, especially in areas that require greater scrutiny. The following examples demonstrate how transparency-focused AI applications can enhance decision-making: in deforestation monitoring, for example, XAI helps identify which land-use factors, like agriculture or urbanization, are driving forest loss, allowing conservationists to focus efforts on the most vulnerable areas (Kaselimi et al., 2023); similarly, in water management, XAI tools reveal key factors impacting groundwater quality, like levels of dissolved solids or electrical conductivity, enabling targeted actions to improve water quality (Alshehri and Rahman, 2023); lastly, in sustainable forest management, XAI highlights causes of ecosystem stress, helping regulators make transparent and responsible decisions (Causevic et al., 2024).

From a strategic point of view, all of these considerations are of immeasurable value to all types of institutions, as the ability to translate algorithmic decisions in a clear and tangible way becomes a differentiator. As we well know, reputation and branding are

crucial external and internal organizational factors, and the adoption of XAI is fundamental to ensure not only regulatory compliance, but also trust and transparency, something that becomes a competitive advantage. Conversely, algorithmic transparency also ensures that environmental decisions are well-founded, a crucial factor for their legitimacy that heightens the interest of global stakeholders from diverse perspectives (Henin and Le Métayer, 2022; Papadakis et al., 2024). To this end, we aim to approach the integration of XAI in environmental governance through a regulatory lens, focusing on the legal implications of transparency, fairness and public accountability. The insights will reflect the unique challenges of adapting AI transparency to a legal framework that protects environmental resources while ensuring equitable access for diverse communities. Therefore, and having established the growing importance of AI in environmental management and the challenges posed by algorithmic opacity, the following sections will explore how XAI addresses these issues by promoting transparency, accountability and public trust.

2. Explainable Artificial Intelligence: trust, transparency and accountability in environmental decisions

The integration of XAI into environmental management and other critical sectors raises essential issues of transparency, accountability, and public involvement. In our digital age, where data and automation shape decision-making, AI systems must go beyond optimizing processes and making complex decisions; they must also deliver clear, accessible explanations to all stakeholders, including citizens, regulators, and companies. Explainability, therefore, is not merely a technical requirement - it is a cornerstone of democratic governance and fairness. Ensuring that stakeholders can understand and scrutinize automated decisions is vital for active participation in decision-making, particularly in fields like environmental management, where the resources are common and impacts are profound and long-lasting. In this way, explainability in AI transcends technical advancement, establishing itself as a crucial pillar of responsible, equitable governance in the digital era (Henin and Le Métayer, 2022).

The concept of XAI is extensively explored in academic literature, particularly regarding how it enhances stakeholders' trust and reduces legal risks. This is because explainability promotes impartiality and robustness, which are critical for companies

aiming to comply with regulations like General Data Protection Regulation (hereinafter, «*GDPR*»). To this end, XAI is described as a growing need in critical sectors due to the opaque nature of many deep learning algorithms, and is also highlighted as a crucial element in ensuring that users can understand, trust and manage AI systems, especially in high-impact areas such as health and criminal justice (Alberto, 2023), whose lessons can now be extrapolated to environmental management. Recent advancements have applied XAI methodologies - such as Layer-wise Relevance Propagation (hereinafter, «*LRP*») and Shapley values - to climate science, enhancing our understanding of annual-mean temperature predictions, regional precipitation forecasts and drought assessments. LRP helps trace back which data points - such as past temperature or rainfall records - significantly influenced the machine's predictions, revealing how different inputs impact the model's outcomes; Shapley values, on the other hand, quantify the contribution of each input variable, like humidity or ocean temperature, to the final prediction, assigning "credit" to factors that shape climate forecasts. These XAI techniques empower stakeholders to gain insights into the underlying patterns and causal factors driving model predictions, thereby improving decision-making and fostering public trust. For instance, in climate prediction, researchers need to interpret temperature and precipitation data to identify significant patterns linked to specific environmental phenomena: by providing clear explanations for model outputs, XAI supports a more informed approach to addressing pressing climate issues. This transparency can be extended to various environmental contexts, such as deforestation monitoring, where XAI can provide clear insights into areas at risk, aiding local authorities and indigenous communities in proactive environmental conservation efforts (Bommer et al., 2024).

The integration of explainability with the Sustainable Development Goals (hereinafter, «*SDGs*») is an important command at this point: undeniably hiper efficient, environmental management provided by XAI can, indeed, be one of the most powerful and effective tools to achieve them, provided that the algorithms operate on the basis of principles of sustainability, transparency and fairness. Moreover, one can also highlight the importance to comply with the "right to explanation" in the GDPR, which requires companies to provide transparency in automated decisions. Compliance with this regulation not only avoids severe fines, but also improves a company's reputation, allowing them to gain consumers' trust by providing clear explanations of how their algorithms work, representing an opportunity for companies to stand out as

leaders in algorithmic accountability. Beyond performance, interpretability guarantees that companies can detect and correct inadvertent biases and systems operate in an ethical manner.

2.1. Challenges with black box algorithms: opaqueness and public trust

The introduction of XAI in environmental management brings both promising opportunities and unavoidable challenges. Explainability allows stakeholders to understand, question and, when necessary, challenge AI-generated decisions (Wani et al., 2024; Zehner and Ullrich, 2024). In critical areas like deforestation control and renewable energy management - where resources are vulnerable and scarce - public trust in the technologies shaping policies is fundamental to their credibility and effectiveness. Yet, one of the major obstacles of the digital age is the opacity of “black box” algorithms, which make decisions through complex, often incomprehensible processes that are protected by trade secrets and intellectual property rights. This opacity can lead to distrust, especially regarding matters of public interest (Maeda et al., 2021). On the other hand, there is a real risk that opaque algorithms could be misused in decisions about natural resources, potentially harming local communities and undermining the public good. In the field of environmental management, trust is crucial for public acceptance of decisions, moreover predictions and optimizations produced by intelligent systems, as well as for ensuring accountability in decisions that affect the environment. This underscores the urgency for fair and accessible solutions that ensure balanced access to and control over these resources. In this context, XAI plays a crucial role, enabling all stakeholders - governments, companies, NGOs and citizens alike - to understand and, if necessary, challenge automated decisions.

For the responsible management of our common assets, it is imperative that these systems be designed to be transparent, trustworthy and comprehensible to all stakeholders. Only then can we achieve ethical and effective stewardship of the environment. By making AI outcomes interpretable without sacrificing predictive accuracy, XAI balances technical efficiency with accountability, ensuring that AI systems are not only effective but also understandable and trustworthy, essential factors for all types of governance. Accountability is thus a cornerstone of implementing AI in environmental management - without clear explanations of how an algorithm reaches specific conclusions, responsibility for errors or injustices remains ambiguous. This issue is even more pressing when it affects vulnerable communities - often the most

impacted by political and environmental decisions - who may lack the resources or expertise to understand these algorithmic processes. This gap highlights the need for more transparent and accessible systems (Mbuva et al., 2024). In sum, these challenges with black-box algorithms underscore the necessity for regulatory frameworks that prioritize transparency and explainability, which we will examine in the next section.

3. Regulatory needs and gaps: towards a global harmonization in XAI governance

Environmental management's digital shift requires more than new technologies and XAI challenges go beyond opaque algorithms, calling for advanced legal and regulatory frameworks. Without these, AI developed by private or research institutions risks fairness in natural resource management. Governing AI effectively demands tailored regulations, accessible explanations for varied audiences and ethical guidelines for responsible development and application (Mbuva et al., 2024). Such measures are vital for ethical and inclusive governance, giving citizens, corporations and governments an equitable voice in environmental decision-making (Zehner and Ullrich, 2024).

3.1. Standards and compliance: fragmented regulatory landscapes and challenges in international compliance

As we all know nowadays, while AI offers substantial advantages, it also presents inherent risks, and the absence of clear rules for algorithmic transparency can undermine public trust, potentially generating resistance to these technologies. The application of AI in sensitive fields like environmental management poses unique challenges, as issues of equity, transparency and accountability are still insufficiently addressed in regulatory dialogues. A major shortfall is the absence of specific, robust regulations for explaining algorithms in environmental resource management, and ensuring that AI systems uphold fundamental rights, such as non-discrimination and data protection, is essential. Without such regulations, the legitimacy of automated decisions - particularly those concerning natural resource distribution - may be questioned, leading to potential conflicts among interest groups and worsening inequalities. The European Commission, for instance, has proposed a regulatory framework that mandates compliance standards, particularly for high-risk AI systems, to enhance transparency and accountability in these technologies (Krafft et al., 2022). AI regulation in the European Union (hereinafter, «*AI Act*») seeks to address these gaps

by establishing ethical and responsible principles for AI development and deployment. While broad frameworks such as the EU's General Data Protection Regulation (hereinafter, «GDPR») establish a “right to explanation” for automated decisions, these measures often fall short of fully addressing the complexities of AI applications in environmental management and need to be developed. Since its enactment in 2018, the GDPR has focused on protecting personal data and supporting individuals' understanding of automated decisions. However, its scope does not encompass the intricate models and specific challenges present in environmental contexts, creating gaps in transparency and accountability. To address some limitations, the AI Act introduces specific guidelines, classifying AI systems by risk level and complementing the GDPR by targeting transparency and explainability requirements, particularly for high-risk applications. Frameworks like the GDPR enforce transparency in automated processes, urging companies to implement explainability practices under the threat of substantial fines and restricted market access. The AI Act further emphasizes that public trust in AI is essential to the progress of technological innovation. While regions like the European Union have established detailed standards, many countries are still in the process of defining their frameworks, which requires global companies to adapt explainability practices to diverse regulatory requirements (Nannini et al., 2023). The international distribution of data centers adds another layer of complexity, as organizations must ensure compliance at both local and global levels, particularly in sensitive areas like environmental data management, human rights and privacy. Moreover, technological infrastructure varies, which can impact an algorithm's ability to provide transparent explanations in regions with less advanced technology. Data security is also a critical concern, as AI-generated explanations must not compromise privacy or data integrity (Chung et al., 2024). Another significant issue for global companies is establishing legal liability across jurisdictions: when algorithms are deployed across different regions, determining responsibility for errors or unintended impacts - such as an environmental failure or consumer rights violation - becomes complex. Gaps in regulation underscore the importance of guidelines aimed at fostering ethical and responsible AI use, particularly in contexts with significant environmental and societal impacts (Krafft et al., 2022). The intersection of regulation, transparency and accountability is essential to ensure AI technologies are used ethically and that automated decisions are fair, understandable and accessible to all stakeholders involved (Krafft et al., 2022). This lack of a standardized approach, sustained on algorithmic

explainability, on a global scale can create legal uncertainty, pushing companies to develop market-specific strategies.

Navigating regulatory requirements is challenging, given the fragmented and evolving nature of AI and environmental regulation globally. All this scenario creates expected and delaying challenges to organizations and professionals, in which one can already anticipate XAI's vital role for global companies and institutions navigating complex regulatory landscapes. For companies operating across multiple jurisdictions, embracing XAI will not only be about regulatory compliance but also about demonstrating social responsibility: by prioritizing transparency and fairness, companies commit to ethics and innovation, enhancing their reputations and attracting investment - especially important in sectors like environmental management, where algorithmic decisions impact sustainability and ecosystem protection (Papadakis et al., 2024).

While harmonizing XAI standards offers numerous advantages, it also presents challenges. Disparities in technological infrastructure and resources among countries could create obstacles for universal implementation; additionally, regulatory inconsistencies across jurisdictions might lead to conflict or non-compliance, potentially undermining public trust in AI applications. While the European Union's AI Act proposes comprehensive regulations that classify AI systems based on risk levels, mandating strict transparency and explainability requirements for high-risk applications, the United States currently lacks a unified federal AI regulation, relying on sector-specific guidelines and principles like the AI Bill of Rights (White House, 2022). This divergence poses challenges for multinational companies striving for compliance and highlights the need for harmonized standards. China has implemented regulations focusing on AI ethics, data security and algorithmic transparency, particularly under the New Generation Artificial Intelligence Development Plan (State Council of China, 2017) - the government's approach emphasizes both innovation and control, requiring companies to ensure AI systems are explainable and align with societal values. Comparing this with the EU's more human-centric and rights-focused framework underscores different regulatory philosophies and the complexities of global harmonization. Countries like Japan and Canada are also establishing AI guidelines that prioritize transparency and ethical considerations (Government of Japan, 2019; Government of Canada, 2020). Addressing these disparities will require international cooperation and adaptive strategies, especially in regions with limited access to advanced AI technologies. As we see, fragmented regulatory landscapes hinder the

development of standardized approaches to AI governance, making cross-border environmental cooperation challenging, and, despite widespread AI adoption, governance and regulation of XAI remain in early stages. Existent frameworks offer some protections, yet there remains a need for legislative measures that increase transparency and accountability in automated decision-making.

The alignment of AI transparency with harmonized environmental standards offers a promising path forward, one that is grounded in the foundational values of equitable and inclusive governance. International consistency is essential for effective natural resources management and climate action. By developing unified XAI standards, organizations and governments worldwide can mitigate the risks posed by regulatory gaps, ensuring that AI applications in environmental management are both reliable and trustworthy, approach that offers a blueprint for future policies in which technology aligns with sustainable development goals through a transparent and accountable framework. The Advisory Opinion issued by the International Tribunal for the Law of the Sea (hereinafter, «ITLOS») on May 21, 2024, came to offer a pivotal framework for addressing such challenges: the opinion emphasized the need for unified international standards to guide state obligations in combating climate change, especially through frameworks that ensure consistent compliance across nations. Applying these principles to the governance of AI in environmental contexts reinforces the need for universal guidelines, which would not only streamline regulatory practices but also foster trust and inclusivity by making AI-driven decisions accessible and transparent to all stakeholders. The Tribunal recommended that states adopt unified legislative frameworks guided by universal rules, establishing a coordinated approach to environmental preservation and sustainable development. This emphasis on harmonization reflects an understanding that fragmented regulations weaken the efficacy of climate action, underscoring the need for a unified global response to ensure that environmental impacts are managed equitably and effectively. Translating this call for harmonization into the governance of AI, especially XAI, reveals the need for coherent standards that ensure environmental management technologies are transparent and ethically sound. In AI-driven environmental systems, uniform regulatory guidelines would address concerns surrounding algorithmic opaqueness, holding AI systems accountable for decisions impacting natural resources and vulnerable communities. Just as ITLOS has highlighted a need for consistent international efforts to protect environments that are analyzed holistically, XAI applications in environmental

management demand a regulatory framework that ensures transparency, accountability and fairness across all the globe.

International organizations, including the United Nations Environment Programme (hereinafter, «*UNEP*») and the International Union for Conservation of Nature (hereinafter, «*IUCN*»), can play critical roles in promoting unified XAI standards on environmental standards. Through collaboration and support for member states, these bodies can help ensure that AI applications in environmental management are aligned with global harmonization objectives, fostering a more cohesive approach to sustainable development. By providing expertise, resources and monitoring, international bodies can strengthen the alignment of XAI governance with broader environmental protection goals. While UNEP and IUCN are positioned to lead unified standards in environmental governance, the responsibility for establishing consistent XAI standards falls to several other international organizations with expertise in AI governance, technology ethics and global regulatory alignment. The International Organization for Standardization (hereinafter, «*ISO*») plays a significant role in developing technical standards across numerous industries, including AI - its ISO/IEC JTC 1/SC 42 committee focuses specifically on AI standards, emphasizing ethical considerations, trustworthiness, and explainability. As a global leader in standard-setting, ISO has the capacity to create XAI frameworks that outline standardized practices for transparency and accountability in AI, making it easier for organizations and governments worldwide to adopt consistent, reliable methods of explainability. These standards could prove essential for ensuring that AI systems in environmental management are universally interpretable and ethical. Another key organization is the Institute of Electrical and Electronics Engineers (hereinafter, «*IEEE*»): IEEE's Global Initiative on Ethics of Autonomous and Intelligent Systems has been instrumental in advancing ethical AI through its IEEE 7000 series, a set of standards focused on ethical considerations in AI and autonomous systems. IEEE's commitment to ethical and human-centered AI design aligns well with the needs of XAI, particularly in ensuring that AI decisions are understandable and accessible to all stakeholders. As a body that balances technical rigor with ethical priorities, IEEE can contribute significantly to creating transparent XAI frameworks that emphasize fairness, reduce bias and make AI decisions accessible and inclusive. The Organisation for Economic Co-operation and Development (hereinafter, «*OECD*») has also established influential AI Principles, endorsed by over 40 countries, which emphasize transparency, accountability and human rights protections in AI. In addition,

the OECD's involvement in the Global Partnership on AI furthers its role in defining best practices for explainable and responsible AI. By providing policy frameworks and guiding principles, OECD could shape regulatory approaches to XAI, ensuring consistency across jurisdictions. For AI applications in environmental management, OECD's standards would ensure that XAI implementations align with global transparency, enabling informed decision-making and public trust. By defining legal requirements for explainability, the EU sets a robust precedent for XAI applications in environmental management: the European Union's regulatory frameworks, particularly the AI Act and the GDPR, are also highly influential - although these frameworks are region-specific, they often set de facto global standards, as demonstrated by the GDPR's wide-reaching influence on data privacy; AI Act categorizes AI applications by risk level, including strict transparency requirements for high-risk AI systems, a classification under which environmental applications of XAI may fall. The EU's standards for XAI provide a rigorous legal framework that could inspire similar global practices, particularly in regions where AI regulation is still evolving. The United Nations Educational, Scientific and Cultural Organization (hereinafter, «UNESCO») adds another dimension to ethical AI through its *Recommendation on the Ethics of Artificial Intelligence*, which represents a pioneering global effort to establish ethical guidelines for AI applications, with an emphasis on transparency, inclusivity and accountability. UNESCO's ethical guidelines have direct relevance for XAI, offering a foundation for standards that ensure AI systems are not only technically sound but also aligned with broader societal values. In the environmental sector, UNESCO's framework would be invaluable for ensuring that XAI models are explainable, fostering ethical practices in applications affecting communities and ecosystems. Finally, the World Economic Forum's Centre for the Fourth Industrial Revolution (hereinafter, «WEF») has actively pursued frameworks and governance models for responsible AI. The WEF's collaborative, multistakeholder approach positions it well to lead discussions on XAI standards, convening governments, businesses and civil society to create a unified, ethical approach to AI. WEF's guidance on XAI could help ensure that AI transparency aligns with global societal needs, especially in areas like environmental management where the impacts of AI-driven decisions are significant and far-reaching.

Indeed, unified XAI standards hold transformative potential for global environmental governance. Coordinated AI policies can facilitate resource sharing, enhance ecosystem resilience and ensure that environmental protections are implemented equitably across

borders; harmonized XAI standards could enable more comprehensive data-sharing initiatives and collaborative research, fostering a globally inclusive approach to environmental stewardship. This model of cooperative governance aligns closely with ITLOS's vision of unified environmental regulation, reinforcing the need for a consistent and transparent approach to AI in environmental management.

3.2. Necessity for public participation and external accountability

It's imperative to consider not only top-down governance but also bottom-up approaches that involve public participation, which we will explore in the subsequent section. A dedicated regulatory framework is essential to ensure public participation in AI-driven environmental management. XAI should foster mechanisms for public engagement, empowering local communities to actively participate in refining models that impact their environment and livelihoods (Zehner and Ullrich, 2024). Promoting active citizen and community involvement in AI decision-making builds public trust and aligns XAI with societal needs. Mechanisms for public engagement allow individuals to review and challenge algorithmic decisions, enhancing transparency and fostering a sense of accountability. Interpretability is crucial in this process, enabling users to assess the alignment of algorithmic outcomes with public interest.

Central to this framework is the requirement for universal mandatory explainability, meaning that all automated decisions impacting natural resources or environmental policies must be accompanied by clear explanations accessible to both specialists and affected communities. By prioritizing explainability and public engagement, XAI in environmental applications can advance beyond technical optimization, providing equitable solutions to pressing ecological challenges.

Public participation, however, is only one component of effective oversight: the ability to audit AI decisions is what fosters trust and promotes ethical and inclusive governance (Barredo Arrieta et al., 2020). Therefore, regulations should also mandate routine, independent audits of these algorithms and their decisions to verify adherence to ethical and environmental standards. An external audit mechanism, free from commercial or political influence, would be critical to upholding justice and equity principles, reinforcing accountability across AI systems (Raji et al., 2022). By integrating public participation with interdisciplinary collaboration, organizations can create an environment where AI meets technical, social and legal demands. This

approach ensures the ethical and transparent development and implementation of technological solutions, addressing governance and accountability requirements in a way that benefits both organizations and society at large.

3.3. Addressing algorithmic bias and equity in environmental management

As machine learning systems play an increasingly pivotal role in environmental governance, they bring critical questions about fairness, transparency and the ethical foundation of their underlying parameters. While providing trust and ensuring that important decisions are transparent and auditable, is being discussed the urgency of developing a rigorous science of interpretability in AI, necessary to ensure that criteria such as safety and non-discrimination are respected (Barredo Arrieta et al., 2020). One fundamental question is: what does “fairness” mean in the context of environmental management? Addressing this requires clear definitions and quantifiable metrics for fairness within each algorithm, establishing an ethical baseline for AI solutions in tackling social and environmental issues. Ensuring fairness in AI-driven decisions is not optional; it is essential to prevent systemic inequalities and environmental injustices (Chakraborty et al., 2020; Zhao et al., 2022).

In environmental policy, XAI should be designed to reduce bias risks that may otherwise favor more powerful regions or groups. Decisions concerning the allocation of natural resources - like water distribution or forest conservation - must avoid privileging affluent sectors at the expense of vulnerable communities. By offering clear and comprehensible explanations of algorithmic decisions, institutions can mitigate legal risks associated with automated decisions, such as potential challenges from users or regulators if outcomes are perceived as unfair or discriminatory. The ability to explain decisions provides companies with an additional layer of protection, helping reduce the likelihood of legal disputes related to algorithmic decisions. Algorithmic audits, such as the Gender Shades study, have driven improvements in facial recognition systems from major companies like IBM and Microsoft, demonstrating that transparency and the correction of biases are not only possible but also generate significant competitive advantage. The correction of these flaws increased the accuracy of the algorithms, improving both consumer trust and product effectiveness. Therefore, establishing trust in AI tools for environmental governance requires aligning technology with justice and inclusivity, particularly for disadvantaged populations who often bear

the greatest impact of automated decisions. Absolute transparency becomes the foundation of this approach, especially for algorithms affecting public resources and quality of life. Regulatory frameworks should mandate full disclosure of the algorithms and data involved, requiring organizations that use AI in environmental management to publish their models, performance metrics and all relevant documentation for public review (Loi and Spielkamp, 2021). Such transparency aligns with ethical guidelines that promote accountability and allow for public audits, reinforcing trust in AI-driven governance.

On the one hand, effective future frameworks must ensure explanations are accessible to both specialists and the public, allowing those affected by algorithmic decisions to engage in decision-making processes. This inclusivity fosters democratic governance and reduces the risk of undermining environmental justice, which seeks to ensure equitable access to natural resource benefits. On the other, for true inclusivity, algorithmic explainability must go in a direction that is accessible to all, regardless of technical background: by making AI outputs understandable, XAI allows diverse communities to fully engage in decision-making processes that affect their lives and environments (Inuwa-Dutse, 2023). This approach, which can only happen through education, is what will address both cognitive biases and prejudices that can enter algorithms.

3.4. Cultural and socio-environmental adaptation of XAI

Adopting and adapting to XAI solutions can enhance regulatory compliance and support ethical, sustainable governance within organizations. Educational and technical training programs are essential for enabling individuals and communities to understand and, when needed, effectively challenge algorithmic decisions. These initiatives not only build public confidence in AI across critical sectors but also strengthen community and regulatory resilience, helping to prevent potential conflicts. This approach fosters credibility among a public that is increasingly critical of institutional practices, while also bolstering the organization's position in the market (Peters and Carman, 2024). At this stage, it is essential for professionals in this sector to understand AI's implications and to provide communities with comprehensive knowledge for meaningful participation - a crucial shift that must be implemented. Achieving algorithm literacy requires focused funding and investment in educational initiatives that make complex AI concepts accessible to diverse audiences. Simplifying algorithm models to enhance

understanding is crucial, as it enables individuals to grasp algorithmic processes more readily. In sum, by funding workshops, creating online resources, supporting technical training and simplifying algorithm models, communities can have an intellectual foundation to build an understanding of how algorithms function and impact their daily lives.

Additionally, as pointed previously, the introduction of AI in managing environmental resources - such as water, air, forests and biodiversity - brings challenges that require a broad understanding beyond technical skills: algorithmic explainability also necessitates adapting explanations to varied social, cultural and linguistic contexts. What constitutes an adequate explanation in one culture may not be sufficient in another; some regions may require detailed technical explanations, while others may prioritize accessible, simplified explanations for the general public (Yang et al., 2023). Such fluidity is crucial for environmental managers to ensure that algorithmic information remains accessible to a broad audience, regardless of their training or background.

3.5. Multi and interdisciplinary collaboration for regulatory compliance

Likewise in environmental regulation, developing and implementing XAI itself requires a multi approach with interdisciplinary cooperation that combines technical, legal and policy expertise, in which the global guidelines previously illustrated would help technical teams adhere to best practices and fostering responsible AI development. The intersection of these fields should be a standard practice, with an ongoing dialogue among different disciplines, which is indispensable for successfully implementing explainable algorithms (Gyevnar et al., 2023; Fresz et al., 2024) and to comply with regulatory requirements while meeting ethical and universal standards, promoting more inclusive and accountable governance.

Legal experts play a pivotal role in navigating this complex regulatory landscape, ensuring what comes first: that explainable algorithms meet standards for data protection, privacy and transparency and assessing the risks of AI, such as potential algorithmic discrimination or automated decisions that could infringe on fundamental rights. Ensuring explainability and auditability is essential to avoid legal consequences stemming from unfair or biased outcomes. Such collaboration is essential, with flexibility to adapt to evolving regulations, such as the GDPR and the AI legislation. In the European context, the need to make algorithmic decisions justifiable and understandable is emphasized, particularly given the complexity of the GDPR and its

limited provisions for a “right to explanation” in automated decisions (Richmond et al., 2024). Technical and legal knowledge should be bridged, fostering clear communication, defining transparency and accountability metrics and addressing any potential conflicts of interest. Continuous interdisciplinary dialogue will ensure that AI solutions are not only effective but also ethical and compliant with existing regulations. Explainability requires a nuanced understanding of an infinite number of legal interactions: at a starting point, one key challenge is translating existing regulations and global guidelines into actionable requirements for technical teams, such as engineers and data scientists, to ensure that algorithms comply with the laws in each jurisdiction where the organization operates, and then adapt them. This collaboration should focus on resolving issues related to algorithmic explainability, regulatory compliance and legal risk mitigation, and plays a crucial role in setting parameters that ensure algorithmic decisions are fair, defensible and transparent to all stakeholders, including regulators and customers. To this end, internal organizational policies need to be developed to uphold algorithmic transparency and assist in creating practices for explainable model design and regular algorithm audits. By integrating legal requirements into technical practices, organizations can develop AI solutions that are both transparent and fair to stakeholders. Such alignment not only mitigates legal risks but also enables AI systems to adapt to a dynamic regulatory environment, where compliance with privacy and transparency laws is increasingly crucial for global operations.

Conclusion

It is beyond question that AI has already become an essential component of our society, making it imperative that we mature in our understanding of both its immense possibilities and its potential risks. The challenge lies in maximizing its benefits while carefully mitigating its drawbacks. We must, therefore, reflect on the kind of society we wish to build and confront the pressing questions posed by the integration of AI into fields like environmental governance. Human rationality may be flawed, yet technology, despite its advancements, is far from perfect. Our algorithms, with all their commendable capabilities, are grounded in qualities that Science has yet to fully refine. They are crafted by humans and, like their creators, they err, carry biases, conceal motives and are molded by prevailing beliefs, much like a judge informed by personal

conviction. But, akin to humans, AI can be regulated, improved and empowered to accomplish remarkable feats.

In environmental governance, transparency and accountability are the pillars for nurturing public trust, particularly as AI takes on greater roles in environmental decision-making. Developing clear standards and encouraging active public participation in these processes will allow AI to serve responsibly, instilling a culture of equity and inclusiveness. This study, therefore, proposes a proactive approach that emphasizes transparency, trust and engagement in AI-driven environmental management, addressing the reality that many environmental decisions are often made under economic and political pressures, with little public involvement. A shift towards more inclusive AI governance allows communities to understand, engage with and influence these decisions directly.

Addressing algorithmic bias and promoting fairness within AI applications are vital for environmental justice, preventing the exacerbation of existing inequalities. To this end, establishing a global regulatory framework centered on XAI is essential for making AI systems transparent and understandable to all stakeholders, thereby strengthening trust and accountability worldwide. Clear regulatory requirements for AI-driven environmental models should be defined to mandate the use of explainable techniques. This ensures that predictions and decisions impacting public resources, such as water and air quality, remain fully accessible and transparent to all stakeholders. As large-scale AI applications operate on an international scale, harmonized standards are essential to maintaining transparency across varied legal frameworks. Without such standards, algorithms risk appearing opaque and unreliable, thereby obstructing effective AI implementation. Thus, internationally unified standards in XAI would support consistent compliance, enabling multinational collaboration. Working with organizations like ISO and IEEE to create guidelines for environmental AI applications can streamline compliance efforts and facilitate a broader sense of accountability. Legislative measures mandating transparency in AI applications - particularly those impacting environmental outcomes - can hold these technologies to stable ethical standards, fostering accountability through a common legal framework.

A structured approach - emphasizing both interpretability and accessibility - fosters inclusivity, enabling stakeholders to understand the key factors in AI-driven decisions. Community engagement platforms, such as public consultations and transparent communication channels, play a crucial role by integrating local knowledge and

aligning AI decisions with societal values. Additionally, educational initiatives are essential for empowering both the public and policymakers to make informed choices and engage meaningfully with AI systems. Introducing educational programs on AI for communities impacted by environmental policies - through workshops, accessible resources and interactive platforms - can enable citizens to understand and actively participate in AI-driven environmental decisions, fostering fair, community-centered outcomes. Simplified models tailored for public understanding would offer an accessible view into environmental issues, transforming AI from a distant tool into an interactive, educational resource. Indeed, by developing educational initiatives around AI and environmental literacy, we empower the people to hold leaders, themselves and everyone accountable, promoting transparent and science-driven environmental policies. Until there, establishing independent auditing mechanisms is essential for verifying the fairness, accuracy and compliance of XAI-driven models in environmental governance. Regular external audits would ensure ongoing accountability, providing assurance that automated environmental decisions meet ethical, legal and environmental standards. Emphasizing data transparency and safeguarding privacy and intellectual property rights within these audits will foster collaboration, drive innovation and strengthen the reliability of AI systems. Also, effective AI governance requires a collaborative approach involving technologists, legal experts, environmental scientists and policymakers to create comprehensive and compliant solutions. Lastly, monitoring advancements and adapting regulations will ensure regulatory frameworks remain relevant and effective. Funding research in XAI methods, especially for environmental applications, will support the development of explainable models without sacrificing their performance.

While the context of climate change does not allow us to wait indefinitely for perfect XAI models, the swift action enabled by current AI tools provides benefits that far outweigh the occasional error, especially in addressing complex environmental issues. By understanding this balance, we establish realistic expectations, recognizing that while AI, like its human designers, is inherently fallible, its speed and accuracy offer invaluable support. Careful regulation and collective oversight will maximize AI's potential, making it a vital instrument in the pursuit of sustainable governance. Ideal transparency in XAI remains an aspirational goal, yet practical steps can pave the way for communities and policymakers to act confidently in the present moment.

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