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Research article

AI-driven participatory environmental management: Innovations, applications, and future prospects

Márcia R. C. Santos [a,b,d,*], Luísa Cagica Carvalho [c]

[a] Universidade Lusófona, Lisboa, Portugal
[b] CETRAD Research Centre, Portugal
[c] Department of Economics and Management, School of Business and Administration, and Resilience, Setúbal Polytechnic University, Setúbal, Portugal
[d] Instituto Universitário de Lisboa (ISCTE-IUL), Business Research Unit (BRU-IUL), Lisboa, Portugal

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ABSTRACT

The rapid advancement of Artificial Intelligence (AI) presents unprecedented opportunities for participatory environmental management. This paper explores the integration of AI technologies into participatory approaches, which engage diverse stakeholders in environmental decision-making processes. Using artificial intelligence, a corpus of 80 papers was compiled and subsequently analyzed with text mining tools. By identifying and systematizing academics' contributions to knowledge about AI-driven tools, this study also discusses the challenges and ethical considerations inherent in AI deployment, emphasizing the need for transparent, equitable, and accountable AI systems. Looking ahead, we outline future prospects for AI in participatory environmental management, focusing on the potential for AI to foster adaptive management strategies, enhance stakeholder collaboration, and support sustainable development goals.

1. Introduction

Artificial Intelligence (AI) is increasingly recognized as a transformative tool in environmental governance, offering advanced capabilities to address complex sustainability challenges. Du et al. (2024) provide a comprehensive analysis of the use of AI in participatory planning through a SWOT framework, identifying its strengths, weaknesses, opportunities, and threats. Their study not only highlights AI's potential to democratize decision-making in spatial planning but also emphasizes the challenges and ethical considerations involved in its practical implementation, particularly in urban and infrastructure contexts. Within the field of environmental studies, AI applications have rapidly expanded, providing effective methods for analyzing and processing environmental data (Konya and Nematzadeh, 2024). The review by Konya and Nematzadeh (2024) identifies key environmental challenges posed by AI, such as energy consumption and carbon footprint, and stresses the need for cooperative efforts between environmental scientists and AI practitioners. They argue for the development of tailored AI frameworks that are both environmentally sustainable and efficient in processing complex datasets. Nishant et al. (2020) highlight the need for an integrated approach to AI for sustainability, advocating for systems thinking and multidisciplinary collaboration to address pressing environmental issues. Their work also explores how adopting culturally sensitive governance practices can reduce resource consumption while fostering innovation in sustainability.

Applications of AI in environmental management are diverse, spanning areas such as climate change mitigation, agriculture optimization, ocean health monitoring, water resource management, weather forecasting, and disaster resilience (Ogundiran et al., 2024; Rautela et al., 2020). These technological advancements extend to energy efficiency in building environments (Ogundiran et al., 2024), sustainable asset management in construction to reduce waste (Rampini and Cecconi, 2022), and blockchain solutions that support low-carbon economies (Rani et al., 2024).

Despite its potential, AI's environmental footprint, particularly regarding energy consumption and carbon emissions, raises concerns about sustainability, calling for the development of eco-friendly AI solutions (Konya and Nematzadeh, 2024). Furthermore, ethical and governance issues must be addressed to ensure AI applications in environmental health align with public welfare goals (Adedayo Adefemi et al., 2023). While AI offers promising avenues for enhancing environmental health, its implementation requires clear governance frameworks to maintain transparency, safety, and ethical standards in technology use (Ansari et al., 2022).

* Corresponding author. Universidade Lusófona, Lisboa, Portugal.
E-mail addresses: marcia.cadete.santos@gmail.com (M. R. C. Santos), luisa.c.carvalho@esce.ips.pt (L. Cagica Carvalho).

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Ongoing advancements in AI necessitate robust regulatory oversight to ensure transparency, safety, and ethical practices in environmental applications (Ansari et al., 2022). This highlights a critical need for further research on policy formation and practical implementation to fully harness AI's capabilities in environmental settings. Addressing these gaps will bridge the divide between AI's potential and its sustainable, practical, and ethical applications in environmental governance (Schiff et al., 2020).

The study seeks to reconcile technological advancement with ecological conservation by underlining scholarly input, pinpointing obstacles, and suggesting methods to merge AI with collaborative approaches. While optimistic about AI's potential, there remains a concern for its limitations and the imperative for comprehensive policies emphasizing continual community engagement and adaptation to specific local circumstances (Chisika and Yeom, 2024). Confronting these obstacles is crucial for fully harnessing AI's potential in participatory environmental governance. Furthermore, the paper outlines potential prospects and directions for future research, providing guidance for successfully incorporating artificial intelligence in participatory environmental governance.

Consequently, this study aims to support these initiatives by addressing the following research questions.

1) What common themes emerged in the study of AI-driven participatory environmental management?
2) What ways can AI be seamlessly incorporated into participatory environmental practices?
3) Which unexplored areas of research could influence how stakeholders participate and collaborate in AI-enabled participatory environmental management?

This research employed an AI tool to organize 80 scholarly papers, analyzing bibliometric information with VOSviewer for term clustering and mapping word co-occurrences, thus synthesizing prior studies. The study consolidates and evaluates extant research to offer an exhaustive summary of present understanding, pinpoint missing pieces in the literature, and underscore potential areas for future investigations. This method underscores the significance of integrating and appraising past studies to yield meaningful revelations about AI's enhancement of participatory methodologies and to discuss public policy considerations for bolstering environmental management tactics.

2. Methodology

This study aimed to provide a comprehensive assessment of AI-driven participatory environmental management through both quantitative and qualitative analyses. These analyses were designed to classify and systematize the available literature, and a critical review to discuss future prospects of AI in this field. The quantitative analysis evaluated the number of papers published in journals (Mas-Tur et al., 2019), while the qualitative analysis concentrated on metrics such as citations per document, which serve as valuable indicators of researchers' productivity and the impact of their contributions (Modak et al., 2020).

A vast number of peer-reviewed articles addressing artificial

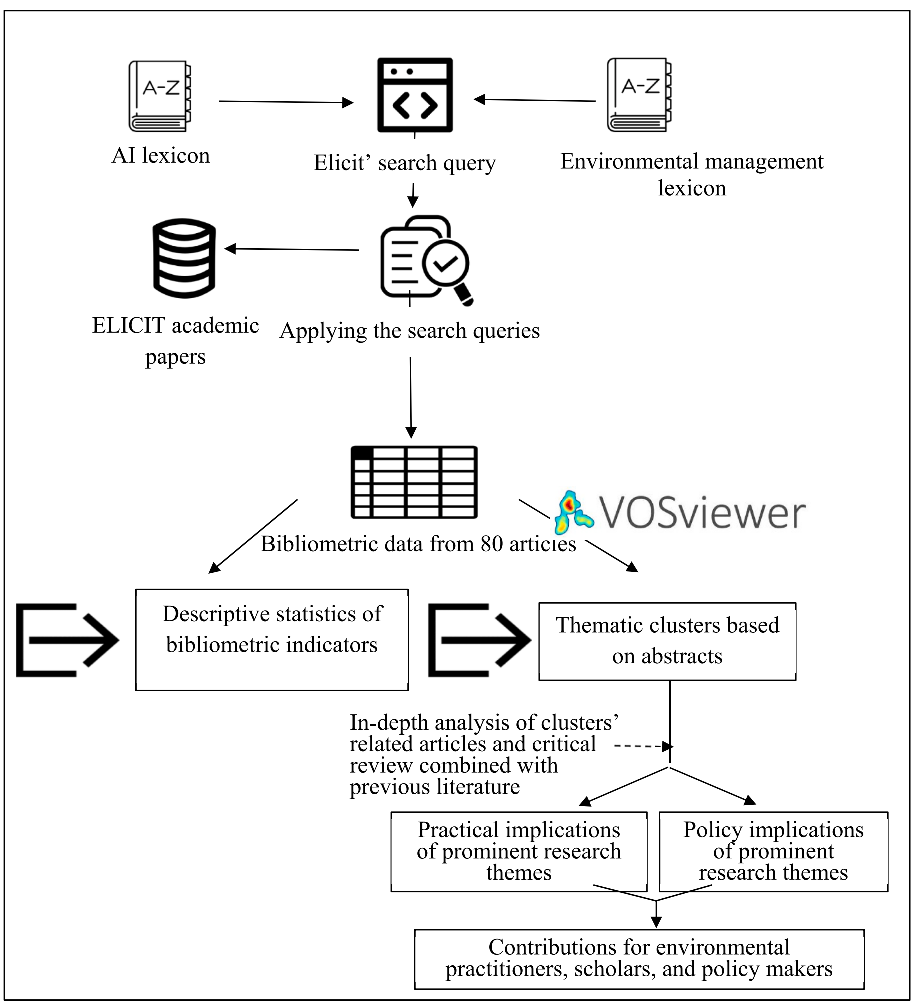

Fig. 1. Research strategy–Workflow outlining the steps from identifying articles with Elicit to bibliometric and thematic analysis for synthesizing results.

intelligence driven participatory environmental management have been published. Manually classifying these publications, identifying their research themes, and uncovering significant patterns would be time-consuming and prone to errors and subjectivity. To address these challenges, automated computer analysis methods have been developed, enabling researchers to efficiently analyze large volumes of bibliometric data and provide a representative, informative perspective on the literature (Modak et al., 2020). Fig. 1 describes full research strategy.

2.1. Data collection

To identify and systematize the relevant papers, we employed Elicit, a literature review search tool that uses large language models to aid the research process. Using Elicit, we ensured that if a paper was available through open access, we could extract and analyze information from the full text for a thorough review. Conversely, if a paper was not open access, Elicit facilitated our reliance on the information provided in the abstract for our assessment. Thus, this AI tool increased efficiency, performed repetitive tasks, and aided with research and analysis (Whitfield and Hofmann, 2023).

Using Elicit, we systematically collected and reviewed 80 papers. Our analysis concentrated on four critical areas, for which Elicit extracted data: methodology, hypothesis tested, future research guidelines suggested, and the policy recommendations proposed by the authors.

This approach allowed us to efficiently gather and organize the necessary data for our research, and enabled us to gain a deeper understanding of the current landscape and effectively inform our own research conclusions.

An overview of the sample highlights that there is a noticeable increase in the number of papers over the last few years, suggesting a growing interest and research activity in the field. The years with the highest number of publications are 2021 (11 papers), 2022 (10 papers), and 2023 (10 papers).

2.2. Text mining and co-word analysis

This study leverages text mining techniques to uncover hidden patterns within the corpus of the documents. Text mining, as detailed by Calheiros et al. (2017), enables the identification of recurring themes and concepts by analyzing the frequency and co-occurrence of words within a given text. Such methodology incorporates stemming and stop word removal to ensure the inclusion of only meaningful terms in the analysis. Stemming is the process of reducing words to their root or base form (e.g., "monitoring" becomes "monitor"), which helps group related words together for analysis. Stop word removal eliminates common words like "paper," "study," "example" as well as terms specific to the literature search (e.g., "artificial intelligence," "AI"), which could otherwise skew the analysis.

The resulting corpus of processed text serves as the foundation for co-word analysis, a technique that reveals relationships between terms based on their co-occurrence within the same paper (van Eck and Waltman, 2009) and group those terms in clusters (van Eck and Waltman, 2017). For this purpose, this study employs VOSviewer, an open-source software widely recognized for its efficacy in bibliometric analysis and visualization (Ghosh et al., 2023; Liu et al., 2024; Santos and Laureano, 2022; Zhang et al., 2023).

2.3. Thematic cluster identification

VOSviewer, utilizing a natural language processing algorithm from the Apache OpenNLP library, constructs network maps that illustrate co-occurrence links between words. This visualization highlights clusters of interconnected terms, with each cluster representing a distinct thematic area within the research landscape. As van Eck and Waltman (2010) suggest, this approach offers advantages over traditional clustering methods, providing a nuanced understanding of complex relationships within the data.

Our analysis focuses on the 60% most significant terms, appearing more than 30 times within the corpus. By analyzing the co-occurrence patterns of these terms, VOSviewer identifies ten distinct thematic clusters.

2.4. In-depth analysis and research implications

Following the identification of thematic clusters, a manual in-depth analysis of articles containing the most frequent terms within each cluster is conducted, using Elicit data extraction output. First, we examined the methodology applied in each study utilized for addressing the research questions posed. Second, we identified and discussed the hypotheses tested across the papers. This step allowed to understand the scope and focus of the research and determining how various studies contributed to the field's knowledge base. Third, we reviewed the policy recommendations proposed by the authors, analyzing the relevance and potential impact of proposed policy recommendations. Finally, we analyzed the future research guidelines suggested within the papers, identifying research gaps and emerging trends to inform future research directions.

This comprehensive analysis provides context and depth to the quantitative findings, revealing specific research trends, knowledge gaps, and promising avenues for future research within each thematic area, ultimately contributing to a roadmap for addressing the challenges faced by organizations when implementing AI-driven participatory environmental management actions.

3. Results and critical analysis

By analyzing word co-occurrence patterns, the study identified thematic clusters within the literature.

3.1. Thematic clusters

Fig. 2 presents a network visualization map created by VOSviewer, where each color signifies one of ten thematic clusters identified within the literature on AI-driven environmental research. The size of each cluster reflects the frequency of the terms it contains, with key themes highlighted. The proximity of terms within each cluster indicates the strength of their co-occurrence, illustrating relationships between concepts. This visualization provides a foundation for understanding how AI applications can support participatory environmental management by aligning technology with stakeholder needs, ethical practices, and regulatory frameworks.

The ten identified thematic clusters within the literature highlight distinct themes within the environmental research domain. AI-enhanced urban health strategies (Cluster 1) emphasizes the intersection of technology and environmental health, focusing on topics such as algorithms, air quality, IoT, neural networks, and their implications for human health in urban settings. Collaborative environmental health systems (Cluster 2) delves into the structural and operational aspects of environmental health, covering networks, deployment parameters, transparency, and trust. This cluster underscores the importance of effective environmental health research and guidelines. Governance and climate resilience (Cluster 3) addresses critical issues related to climate change, disaster management, and governance, emphasizing the need for effective environmental governance and protection measures. Community-integrated resource management (Cluster 4) focuses on community involvement and the management of natural resources, highlighting the role of GIS, public participation, and spatial data in environmental management. Innovative technologies for environmental solutions (Cluster 5) explores ICT projects, like blockchain, as initiatives for contributing to nature and life. Sustainable environmental science and data (Cluster 6) integrates advanced techniques like data mining

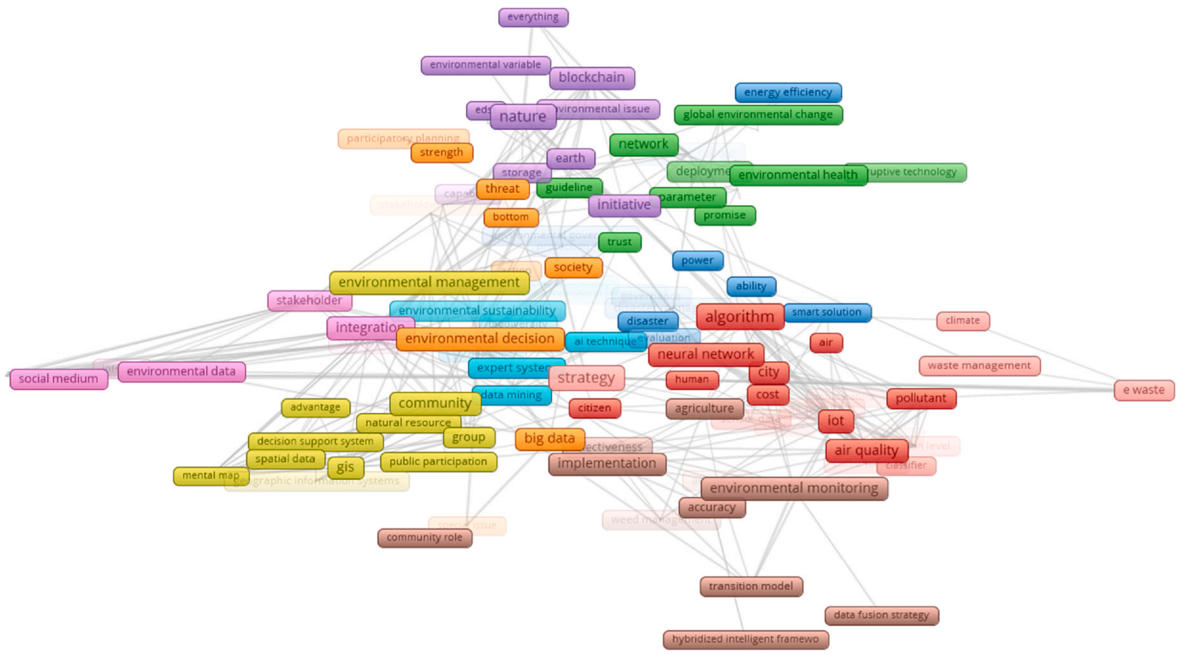

Fig. 2. VOSviewer network visualization of ten thematic clusters in AI-driven environmental research.

and AI with sustainability and biodiversity, reflecting the interdisciplinary nature of modern environmental science. Inclusive environmental decision-making (Cluster 7) examines the decision-making processes in environmental contexts, emphasizing big data, stakeholder involvement, and participatory planning. Precision monitoring in agriculture and environment (Cluster 8) addresses practical aspects of environmental monitoring and agricultural practices, focusing on implementation, accuracy, and community roles. Smart infrastructure for sustainable environments (Cluster 9) highlights the integration of smart technologies and infrastructure in environmental sustainability, covering topics such as digital twins and intelligent environmental infrastructure. Lastly, strategic waste and resource planning (Cluster 10) focuses on strategic approaches to waste management, climate impact, and life cycle assessment, underscoring the importance of extended producer responsibility and multi-criteria analysis in developing effective environmental strategies. Table 1 lists the most frequent terms in each cluster and each term's number of occurrences.

3.2. Methodology applied in AI-driven participatory environmental management research

Literature review and systematic review are the most frequently used methodologies, indicating a strong emphasis on synthesizing existing research in the field of AI and participatory environmental management. The frequent use of literature and systematic reviews suggests a focus on consolidating existing knowledge rather than generating new empirical data. This could indicate a nascent field where foundational understanding is still being developed.

Nonetheless, the majority of the study are divided by a variety of methodologies, from case studies (Chisika and Yeom, 2024) to optimization algorithms (Asha et al., 2022), which underscores the interdisciplinary nature of the field. The methodology section reveals that current studies are incorporating methodologies tied to IoT (Kamyab et al., 2023), or digital twins (Prandi et al., 2022), indicating a movement towards the adoption of advanced technologies in the field of environmental management. By using participatory methods, like Participatory Geographic Information Systems (PGIS) and community-based surveys, authors highlights the importance of stakeholder engagement in environmental management (Jankowski, 2009; Kankanamge et al., 2021). Finally, AI-powered chatbots are emerging as valuable tools for enhancing community engagement by providing accessible platforms for stakeholders to report environmental issues and receive real-time information, thereby streamlining communication between local authorities and the public (Denecke et al., 2019). Machine learning models also play a critical role in agricultural management, where they predict soil conditions and crop yields (McElhinney et al., 2022; National Academies of Sciences, 2019), supporting sustainable practices and enabling stakeholders to make informed decisions about land use.

3.3. Hypothesis tested in AI-driven participatory environmental management research

In literature, authors evaluate research hypotheses using empirical analysis across seven studies. Chakim et al. (2023) examined the factors influencing the adoption of AI-enhanced air quality systems, looking at aspects like performance expectations, effort expectations, social influence, facilitating conditions, and awareness of air pollution. This study offers key insights into the behavioral intentions and actual use of such systems. It highlights the importance of understanding user acceptance and the practical implementation of AI technologies in environmental management. In participatory forest management, Chisika and Yeom (2024) tested and validated that integrating AI into participatory forest management (PFM) can improve the efficiency, timeliness, and accuracy of community roles in data acquisition and management. Their study emphasizes the necessity of leveraging existing ICT resources, such as smartphones, and ensuring continuous community engagement for successful AI implementation in PFM.

Hypotheses related to AI in disaster management reflect the growing interest in leveraging AI to improve disaster preparedness and response. Understanding demographic differences in the appreciation and understanding of AI benefits can inform targeted educational and training programs. This was what Kankanamge et al. (2021) found when testing whether or not younger generations and people with tertiary education had a greater appreciation and understanding of AI-driven applications for disaster management.

Researchers are concentrating on employing AI techniques to enhance air quality assessment. Ahmed Hamza et al. (2022)

Table 1
Clusters' characterisation.

Cluster	Most frequent terms	Number of occurrences
Cluster #1 (red): AI-enhanced urban health strategies	algorithm	289
	air quality	197
	iot	188
	neural network	174
	city	123
	internet	105
	pollutant	104
	human health	77
	air pollution	77
	cost	74
Cluster #2 (green): Collaborative environmental health systems	network	151
	environmental health	102
	deployment	74
	parameter	72
	contribution	70
	transparency	66
	trust	59
	interpretability	51
	guideline	48
	environmental health research	45
Cluster #3 (dark blue): Governance and climate resilience	climate change	133
	disaster management	108
	ecosystem	102
	planet	60
	evaluation	58
	governance	53
	disaster	51
	environmental governance	49
	ability	48
	protection	47
Cluster #4 (yellow): Community-integrated resource management	community	179
	environmental management	170
	gis	146
	resource	142
	group	110
	spatial data	66
	natural resource	57
	geographic information systems	50
	public participation	47
	map	44
Cluster #5 (purple): Innovative technologies for environmental solutions	nature	263
	blockchain	143
	initiative	125
	earth	72
	communication	71
	storage	59
	environmental issue	58
	capability	57
	life	50
	everything	40
Cluster #6 (light blue): Sustainable environmental science and data	environmental science	93
	environmental sustainability	81
	expert system	76
	data mining	67
	time	65
	smarter eco city	57
	ai technique	53
	environmental protection	48
	biodiversity	46
	environmental informatics	37
Cluster #7 (orange): Inclusive environmental decision-making	environmental decision	190
	big data	159
	threat	87
	society	78
	action	69
	strength	51
	complexity	50
	participatory planning	49
	stakeholder involvement	46
	participatory	41
Cluster #8 (brown): Precision monitoring in agriculture and environment	environmental monitoring	195
	implementation	122
	effectiveness	111
	adoption	111
	accuracy	109
	agriculture	84
	transition model	68
	weed management	52
	community role	37
	data fusion strategy	33
Cluster #9 (pink): Smart infrastructure for sustainable environments	integration	180
	sustainability	160
	stakeholder	111
	environmental data	99
	social medium	79
	interest	43
	digital twin	42
	smartlagoon project	33
	intelligent environmental infrastructure	32
	child	31
	mar manor	31
Cluster #10 (light red): Strategic waste and resource planning	strategy	282
	e waste	82
	waste management	63
	climate	34
	extended producer responsibility	32
	multi criteria analysis	31
	life cycle assessment	31

demonstrated that tools such as the air quality prediction and classification (OAI-AQPC), ARIMA-NN model, oppositional swallow swarm optimization (OSSO) algorithm, and adaptive neuro-fuzzy inference system (ANFIS) classifier can accurately forecast and categorize air quality, suggesting a drive to refine the precision and dependability of environmental data gathering and forecasting.

Within the realm of electronic waste, research highlights the capability of artificial intelligence to enhance environmental strategies for addressing toxic contaminants (Chen et al., 2021). investigated the application of AI in identifying and evaluating hazardous substances in e-waste, and in improving e-waste management through approaches such as life cycle assessment (LCA), multi-criteria analysis (MCA), and extended producer responsibility (EPR).

Finally, research also indicates that AI and digital tools can boost energy efficiency, improve carbon trade, and achieve nations' goals for a circular economy (Jose et al., 2020).

3.4. Policy recommendations in AI-driven participatory environmental management research

From recent studies focusing on the integration of AI in environmental management emerge recommendations for policymakers, researchers, and practitioners to effectively leverage AI technologies for sustainable environmental practices. The policy suggestions have been categorized into clusters to highlight common themes and priorities across different areas of study (Table 2). By clustering policy recommendations, this study highlight scholars' important contributions to supporting governments and organizations dealing with this environmental management supported by AI.

Clustering policy recommendations from the analyzed literature

Table 2
– Policy recommendations in AI-driven participatory environmental management research.

Cluster	Practical implications	Policy recommendations	Studies
Community engagement and local adaptation	Prioritize continuous adaptation of AI to local contexts, ensuring active community involvement in environmental decision-making processes.	Develop comprehensive AI policies emphasizing community engagement and local adaptation	(Adefemi et al., 2023; Chisika and Yeom, 2024)
Data privacy and ethical use	Establish clear consent mechanisms and robust data privacy guidelines to protect sensitive information, ensuring algorithmic transparency and ethical AI usage, especially in resource-constrained regions.	Establish data privacy guidelines, ensure algorithmic transparency, and promote ethical AI use	(Adefemi et al., 2023; Krupnova et al., 2022; Onyebuchi Nneamaka Chisom et al., 2024)
Disaster management	Develop integrated GIS and AI systems for disaster prediction and response, enabling inclusive community preparedness through improved data visualization and analysis.	Consider public perceptions, develop comprehensive AI deployment plans, and leverage GIS for disaster management	(Abid et al., 2021; Kankanamge et al., 2021)
Environmental monitoring and conservation	Leverage AI to analyze large environmental datasets (e.g., drone imagery, GPS data) for real-time monitoring, facilitating rapid and effective responses in conservation efforts.	Implement regulatory oversight, support research, and deploy blockchain technology	(Fan et al., 2023; Sivarethinamohan and Sujatha, 2021)
Circular economy and waste management	Implement collaborative, AI-driven solutions to enhance recycling, reuse, and eco-design processes, optimizing waste management and minimizing environmental impact.	Support collaborative circular economy initiatives and develop eco-design systems for e-waste	(Chen et al., 2021; Shennib and Schmitt, 2021)
Water monitoring and management	Utilize remote monitoring and AI to forecast and assess water quality, supporting improved water resource planning and swift responses to pollution.	Improve water resources management systems and implement "no regrets" strategies for climate resilience. Inform public policy planners for better environmental preservation and restoration decisions	Yang et al. (2022)
AI integration and capacity building	Foster workforce development and partnerships in AI applications to drive innovation and strengthen human capital within the environmental sector.	Emphasize partnerships, develop expertise, and promote workforce training	(Boukabara et al., 2021; Paul, 2020)
Air quality monitoring	Expand monitoring coverage through additional stations and advanced computational forecasting methods, ensuring timely, data-driven air quality interventions.	Increase monitoring stations, develop computational methods, and prioritize air quality forecasting	(Subramaniam et al., 2022; William et al., 2023)
Sustainable precision agriculture	Employ AI to monitor and optimize agricultural inputs, promoting sustainable practices and reducing the environmental footprint of agriculture.	Transform production methods with technological solutions	Linaza et al. (2021)
Innovative solutions and smart systems	Adopt AI-integrated sediment analysis to optimize ecosystem management in aquatic environments, reducing the need for disruptive interventions.	Adopt AI-integrated sediment analysis and remote sensing solutions for optimal decision-making	(Majidi et al., 2021; Shah, 2024)

reveals three key areas requiring action from governments and organizations: (1) funding and incentives, (2) human capital development, and (3) technological infrastructure and ethical frameworks.

In the first field, governments should establish dedicated funding lines to support AI projects in key areas like community-based initiatives, circular economy solutions, and water monitoring improvements. Grants, tax breaks, and other incentives should be offered to encourage the development and implementation of innovative AI solutions for environmental challenges. Governments should also foster collaborations between public and private entities to leverage additional funding sources and expertise. Finally, governments can incentivize international partnerships to facilitate knowledge exchange and development of adaptable AI solutions across different regions.

In the human capital development area, public policies should support the development of educational programs focused on AI, data science, environmental management, and interdisciplinary approaches. Governments can also promote training programs for professionals in the public and private sectors to enhance their understanding and skills in AI technologies for environmental management. Additionally, public policies can encourage the inclusion of community engagement modules in educational curricula to equip future AI professionals with the skills to involve local communities in project development and implementation.

In the third identified area (i.e., technological infrastructure and ethical frameworks), governments can invest in developing robust AI infrastructure, including data centers, high-performance computing facilities, and comprehensive data collection and management systems. They can also prioritize research and development of new AI algorithms, blockchain technology, and other advanced technologies to enhance environmental monitoring, conservation, and disaster management. Public policies can impact by facilitating the transfer of knowledge and innovation from academia to the corporate sector to foster practical applications of AI in environmental management. Finally, governments can develop and implement regulatory frameworks to ensure the ethical, transparent, and privacy-conscious use of AI in environmental applications. AI-powered chatbots and machine learning models also support policy development by facilitating real-time communication with the public and providing predictive insights for sustainable land use and agricultural management. These technologies exemplify how AI can bridge the gap between policy frameworks and practical implementation, enhancing stakeholder engagement and data-driven decision-making.

3.5. Future research guidelines in AI-driven participatory environmental management research

An examination of suggested areas for future research uncovers a wide array of topics extending through various fields. Principal groupings encompass artificial intelligence strategies and regulations, technological advancement, sustainable and ethical practices, and cross-disciplinary cooperation. Fig. 3 highlights the foundational elements needed for advancing AI research in participatory environmental management. Cross-disciplinary cooperation is central, linking AI strategies and regulation, sustainable and ethical practices, and technology development. These areas are essential for creating frameworks that support responsible and effective AI integration in environmental decision-making processes.

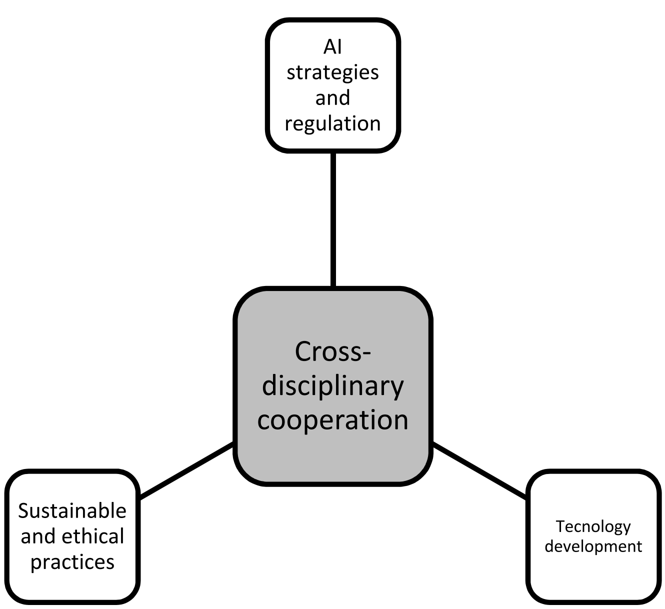

Fig. 3. – Key areas for future research in AI-driven participatory environmental management.

First, literature highlights the pressing need for research focused on developing robust AI solutions for environmental management while simultaneously addressing the ethical, policy, and governance challenges they present. Indeed, several authors emphasize the importance of developing and evaluating AI-based solutions for specific environmental management tasks, such as participatory planning and public financial management (Chisika and Yeom, 2024). Research should prioritize identifying and addressing the limitations and challenges of these technologies, particularly in ensuring equitable and democratic outcomes. Furthermore, there is a clear call for comprehensive AI policies and legislative frameworks (Ansari et al., 2022; Onyebuchi Nneamaka Chisom et al., 2024). These frameworks should address responsible AI use, data governance, ethical considerations, and potential societal impacts. Nishant et al. (2020) advocate for a multidisciplinary approach to policy development, incorporating insights from systems dynamics, design thinking, psychology, sociology, and economics. This holistic perspective will be crucial in ensuring that AI technologies are developed and deployed in a manner that benefits both the environment and society as a whole.

In technological advancement arena, literature emphasizes the need for continuous technological advancement in AI-driven environmental management. Several authors highlight the potential of robotic systems and AI-driven sensors for monitoring extreme and challenging environments (Popescu et al., 2024). Further research should focus on enhancing the modeling and predictive capabilities of digital twins and evaluating their effectiveness in environmental decision-making (Prandi et al., 2022). Beyond these specific technologies, there is a broader call to further develop AI models across various environmental fields and integrate AI into environmental governance and decision-making processes. This includes developing scalable AI algorithms and integrating them with next-generation wireless networks (Fan et al., 2023), as well as enhancing AI methods for forecasting and developing more interpretable AI models (Haupt et al., 2009).

Finally, regarding sustainable and ethical practices, researchers emphasize the importance of developing socially responsible AI approaches for environmental decision-making to ensure ethical and equitable implementation (Li et al., 2021). Indeed, there is a strong emphasis on developing AI solutions that directly address pressing environmental challenges, such as intelligent water monitoring systems (Yang et al., 2022), efficient natural resource management strategies, and AI-powered tools for urban planning (Urban et al., 2021). Several authors advocate for integrating AI with other technologies and approaches, such as remote sensing, GIS, IoT, and big data analytics, to create more comprehensive and effective solutions. For instance, Ahmed Hamza et al. (2022) suggest developing integrated frameworks combining these technologies, while Abid et al. (2021) highlight the potential of remote sensing and GIS for environmental informatics. In the same path, Adefemi et al. (2023) call for standardized ethical guidelines for AI development and use, while Pachot and Patissier (2023) stress the importance of making AI environmentally sustainable by integrating environmental indicators into AI systems.

Furthermore, and as a transversal concern, researchers highlight the need for interdisciplinary collaboration, data sharing initiatives, and the development of managerial tools to ensure the responsible and equitable deployment of AI for a sustainable future (Shennib and Schmitt, 2021).

5. Conclusion

This study underscores the pivotal role of AI in advancing environmental management practices. By systematically reviewing the literature and identifying thematic clusters, it is evident that AI technologies are instrumental in addressing a myriad of environmental challenges. The integration of AI in environmental monitoring, decision-making, and management has demonstrated significant potential in enhancing accuracy, efficiency, and scalability.

5.1. Main findings

Key insights from this research highlight the need for tailored AI solutions that address specific inefficiencies in environmental management. The development of robust AI-based systems for participatory planning and public financial management showcases the versatility and applicability of AI in diverse environmental contexts. Additionally, the importance of establishing comprehensive AI policies that prioritize ethical considerations and community engagement is paramount. Such policies will ensure that AI technologies are implemented in a manner that is both equitable and inclusive.

Technological advancements in AI, including the development of sophisticated tools like robotic systems and enhanced predictive models, are crucial for the continuous improvement of environmental monitoring and decision-making processes. Furthermore, integrating AI with other emerging technologies such as IoT, GIS, and big data analytics can lead to more comprehensive and effective environmental solutions.

In this path, sustainability and ethics must be central to future AI research endeavors. This involves not only developing environmentally sustainable AI systems but also ensuring that ethical considerations are integrated at every stage of AI development and deployment. Such an approach will help mitigate potential negative impacts and promote the responsible use of AI in environmental management.

Finally, international cooperation and interdisciplinary collaboration are essential for scaling AI solutions across different geographic contexts. By fostering collaborative efforts and leveraging diverse expertise, it is possible to develop comprehensive and holistic solutions that address global environmental challenges.

5.2. Practical applications and policy implications

This study identifies several avenues emerging from previous studies through which AI can enhance participatory environmental management, with practical applications already found in real-world contexts. Studies provide evidence that GIS combined with AI enable stakeholders to participate actively in environmental planning by visualizing impacts in real time. In urban areas, AI-driven air quality monitoring systems provide residents and policymakers with up-to-date information, empowering them to make informed decisions about air quality interventions. Predictive AI models used in disaster management help communities prepare for risks, fostering inclusivity in decision-making processes by involving residents in pre-emptive planning. Additionally, AI-powered chatbots facilitate community engagement by providing accessible platforms for reporting environmental concerns, such as illegal waste disposal or deforestation, allowing local authorities to respond more efficiently. Machine learning algorithms are also applied in agricultural management to predict soil health and crop yields, enabling farmers to adopt sustainable practices while involving them in collaborative decision-making for land use. These examples illustrate the potential of AI to support diverse, stakeholder-focused approaches in environmental governance, demonstrating its capacity to enhance participatory engagement at multiple levels.

To harness the full potential of AI-driven tools in participatory environmental management, targeted policy actions are essential. Practical insights from this study — such as the impact of AI on real-time data access, community engagement via AI-powered chatbots, and predictive capabilities through machine learning models — highlight the pressing need for supportive policies. For instance, incentivizing public-private partnerships can magnify the benefits of these AI tools by fostering collaborative efforts that unite governments, communities, and private entities around shared environmental goals. Transparent data-sharing frameworks are also critical to operationalize these practical tools, allowing stakeholders to access, share, and analyze data collaboratively, thereby reinforcing trust and transparency. Moreover, regulatory guidelines that ensure ethical AI usage and data privacy are essential for aligning AI applications with sustainable and inclusive governance standards. These policy recommendations serve as a call to action for policymakers, providing a roadmap to translate AI's practical applications into effective, responsible, and collaborative frameworks for environmental governance.

5.3. Ethical considerations

From studies emerge ethical imperatives that are essential for responsible AI deployment in participatory environmental management. Ethical frameworks must prioritize transparency, actively prevent biases, and protect data privacy, as these elements are foundational to fostering trust and ensuring fair, inclusive outcomes. These frameworks should include guidelines for data collection and processing that mitigate existing biases, particularly in datasets representing diverse communities or sensitive environmental information. Transparency policies are also vital, enabling stakeholders to understand and scrutinize AI decision-making processes, thus enhancing accountability at every stage. Additionally, robust privacy protections are crucial when AI systems handle personal or community-specific environmental data. By establishing and adhering to these ethical principles, practitioners can avoid common pitfalls, ensuring that AI applications not only achieve environmental goals but also uphold social responsibility. These ethical frameworks provide a foundation for integrating AI in a manner that is both innovative and principled, aligning with sustainable development goals to promote long-term benefits in environmental management that are resilient and inclusive.

5.4. Limitations

Like all research, this study had its limitations. The selection of data was limited to peer-reviewed articles in academic databases, yet it's possible that including non-academic literature from environmental management practitioners might have offered additional insights.

The automated analytical approach using text mining employed in this research yielded outcomes more rapidly and without subjective bias. Furthermore, the research employed Elicit as an artificial intelligence-based instrument for data extraction from scholarly articles, streamlining repetitive processes. It should be noted, however, that some scholars still favor the conventional systematic literature review methods that involve manually examining each paper.

CRediT authorship contribution statement

Márcia R. C. Santos: Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **Luísa Cagica Carvalho:** Writing – original draft, Resources, Conceptualization.

Compliance with ethical standards

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Declaration of competing interest

The authors declare that they have no conflict of interest.

Data availability

The data is academic articles' corpus which is publicaly available.

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Márcia R. C. Santos. (marcia.cadete.santos@gmail.com) Professor at Universidade Lusófona, Portugal, Instituto Universitário de Lisboa (ISCTE-IUL), Business Research Unit (BRU-IUL), Lisboa, Portugal; ORCID: 0000-0001-8741-0122 (https://ciencia.iscte-iul.pt/mrcss/en)

Luisa M. Cagica Carvalho (PhD, luisa.c.carvalho@esce.ips.pt) is Associate Professor at Department of Economics and Management, School of Business and Administration, Setúbal Polytechnic University, Portugal, and Resilience research center. She has authored several works on sustainability and has significant citations and recognition in her field. Her research interests include entrepreneurship, innovation, services, and tourism. ORCID: 0000-0002-9804-7813