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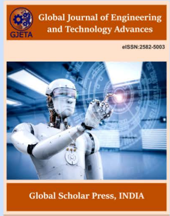

(REVIEW ARTICLE)

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Role of AI in reducing global Plastics use: Predictive analytics for global sustainability

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Abstract

The growth, from a global perspective, in plastic waste sees its necessary promise in Artificial Intelligence. The driving force of Machine Learning, Computer Vision, and Predictive Analytics, shapes each style of waste management and effective collection routes to recycling. In this paper, therefore, the discussion will be on how AI can ensure a reduction in plastic waste, focusing on developing countries such as Nigeria. The theoretical underpinning of this research is on AI adoption, the Technology Acceptance Model, a few real-world case studies in AI for waste reduction, and many challenges that need to be focused on due to issues of data sparsity, infrastructure limitations, and ethics. Using these challenges for unlocking the full potential of AI in the direction of a more sustainable future, with minimal plastic waste at the forefront of environmental well-being, could be better negotiated. As the global community faces the pressing need to tackle plastic pollution, especially in areas with inadequate waste management systems and severe environmental challenges AI technologies present groundbreaking solutions to improve waste management methods, eliminate environmental harm, and foster sustainable growth. A crucial factor influencing the future of AI-driven plastic waste reduction in developing countries is the ongoing progress and implementation of AI technologies.

Keywords: Global Plastics; AI; plastic waste management; Pollution

1. Introduction

Global plastic production has seen a significant surge owing to its versatile applications resulting in a large volume of plastic waste polluting the environment[1]. Plastic pollution poses a critical global problem, causing harmful effects on ecosystems, human health, and economies, especially evident in developing nations like Nigeria where inadequate waste management systems worsen the situation. [2]. With global plastic production exceeding 359 million metric tons yearly, and over 8 million tons of this waste entering oceans each year, decisive action is necessary. [3]. Plastic waste not only sullies natural landscapes and obstructs water bodies but also significantly endangers wildlife through ingestion and entrapment. [4]. As communities confront this crisis, adopting artificial intelligence (AI) presents a viable strategy for addressing plastic waste, utilizing technology to improve waste management methods. AI, which includes machine learning, natural language processing, and computer vision, replicates human cognitive functions in executing tasks, providing novel solutions to intricate challenges.[5]. In the field of waste management, AI has considerable promise to streamline tasks such as waste collection, sorting, and recycling, ultimately mitigating plastic waste and environmental harm. [6].

The appeal of AI-based methods for reducing plastic waste lies in their capacity to improve efficiency and effectiveness throughout waste management. By leveraging data analysis, machine learning techniques, and robotics, AI technologies can transform waste collection systems, facilitating predictive analytics that optimizes routes and schedules, thus diminishing resource use and carbon emissions. [7]. Additionally, AI-enhanced sorting technologies boost recycling

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processes, enhancing the quality and quantity of recycled materials while lowering contamination levels. [8]. These developments are especially relevant globally, where the lack of a solid waste management infrastructure highlights the need for innovative solutions [9].

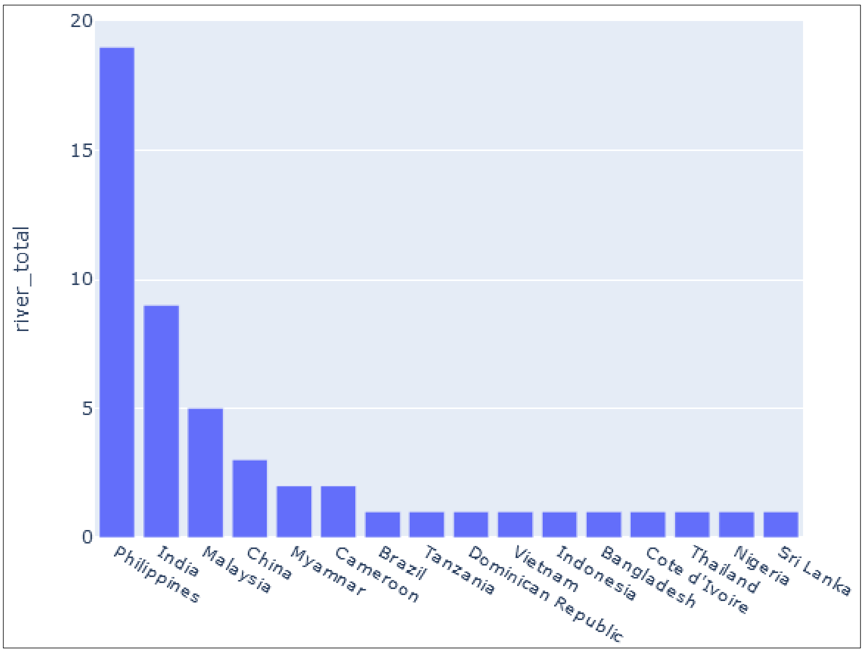

Figure 1 Bar chart of global plastic emission

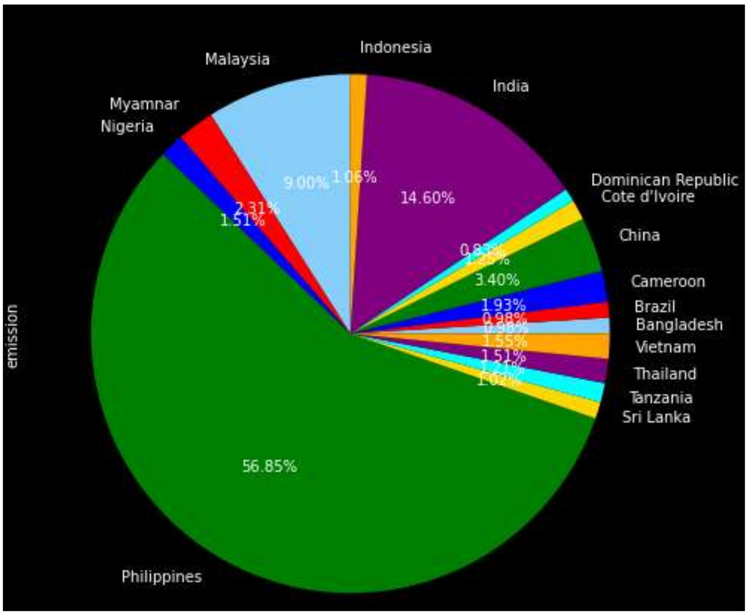

Figure 2 Pie chart of global Plastic Emission

A variety of case studies and research projects globally highlight the effectiveness of AI in initiatives aimed at reducing plastic waste. For example, the Philippines shows the highest deposit percentage of Plastic deposition in rivers, while India has the second largest deposition of plastic pollution in rivers as shown in Figure 1 and Figure 2 above. In Taiwan, robotic systems powered by AI have been introduced in recycling facilities to automate the sorting process, resulting in enhanced efficiency and improved resource recovery rates [10]. Likewise, European countries, such as Germany and the Netherlands, have implemented AI-enabled waste collection systems that have shown notable advancements in route optimization and waste diversion rates [11]. These examples provide insightful perspectives on how AI could be applied in Nigeria, motivating customized strategies to tackle the country's distinct challenges [12]. However, the incorporation of AI into plastic waste reduction efforts presents its own set of challenges and limitations. Technical issues, including a lack of data and bias within algorithms, are significant obstacles to the creation and deployment of AI technologies for waste management [6]. Additionally, the substantial initial investment required for implementing AI may hinder widespread adoption, particularly in resource-limited environments. Data privacy and cybersecurity also need to be addressed to ensure the ethical and responsible usage of AI in waste management[13] [14].

Tackling these challenges necessitates a comprehensive approach that includes a variety of viewpoints and stakeholders. Collaborative alliances among government bodies, research organizations, industry participants, and civil society groups are vital to fostering innovation and promoting knowledge exchange in the realm of AI-driven waste management [14] . Furthermore, initiatives focused on building capacity to equip local communities with the necessary skills and knowledge to utilize AI technologies can improve sustainability and encourage inclusive growth [15]. Moreover, the convergence of AI and plastic waste reduction serves as a cutting-edge area of innovation with significant implications for environmental sustainability and social advancement. Despite existing challenges, the transformative potential of AI in enhancing waste management practices is undeniable. By leveraging the capabilities of technology and encouraging collaboration, developing nations can move towards a cleaner, more sustainable future, where plastic pollution is diminished, and ecosystems flourish. Efforts aimed at addressing plastic waste through AI-driven solutions should also be supported by strong regulatory frameworks, community involvement, and infrastructure investments to ensure their long-term effectiveness and sustainability.

2. Understanding the Plastic Waste Crisis Globally

Plastics are among the most widely used materials globally. They are integral to our daily lives, yet significant health risks are linked to plastic pollution, potentially leading to increased healthcare expenses across the nation. It is crucial to comprehend the impact of plastic pollution on health and how reducing it might decrease medical costs and improve public health outcomes. Additionally, there are various concerns beyond disposal, such as waste accumulation in natural settings and landfills, physical harm to wildlife from ingestion or entrapment in plastic, chemical leaching from plastic products, and the potential for plastics to transfer harmful substances to both humans and the environment [16].

The crisis of plastic waste presents a significant environmental challenge in developing nations, due to its rapidly growing population, urbanization, and economic development, developing nations struggle with the increasing accumulation of plastic waste, worsened by insufficient waste management systems and practices [17]. The dependence on single-use plastics, along with a lack of recycling facilities and informal waste disposal methods, further fuels the spread of plastic pollution throughout its landscapes, waterways, and urban areas[7]. The consequences of this crisis are extensive, affecting ecosystems, public health, and socioeconomic advancement. Plastic waste compromises soil, water supplies, and marine environments, threatening biodiversity and the functioning of ecosystems.[7]. Additionally, the incineration of plastic waste emits harmful pollutants into the air, worsening air quality and respiratory issues among communities near waste disposal locations [18]. The economic ramifications of plastic pollution are also considerable, impacting tourism, fisheries, and agriculture while hindering progress toward sustainable development goals. [19].

A thorough analysis of relevant studies on plastic waste management globally provides valuable insights into the diverse challenges, existing practices, and potential solutions regarding this pressing environmental concern. Solaja [7] Highlights the concerning rate at which Nigeria produces plastic waste, estimating an annual total of over 32 million tons. This alarming statistic emphasizes the urgent need for effective waste management strategies in the country, as the improper disposal of plastic waste poses serious environmental and public health threats. The authors note that a significant amount of this waste ends up in landfills, water bodies, and informal dumping sites due to insufficient waste management systems, worsening environmental pollution, and endangering ecosystems.

Tackling the plastic waste crisis in Nigeria requires a comprehensive strategy that combines policy interventions, public awareness initiatives, and investments in waste management infrastructure. Programs like the Extended Producer Responsibility (EPR) scheme, which holds manufacturers accountable for the post-consumer management of their products, present promising opportunities for reducing plastic waste generation and encouraging recycling. [20] .

In addition, community-driven waste management programs, along with incentives for collecting and recycling plastic waste, can empower local stakeholders to actively engage in waste reduction efforts. [21]. Educational and awareness initiatives are essential in transforming attitudes and behaviors regarding plastic consumption and disposal, stressing the need for waste segregation, reuse, and recycling. [7]. Collaborative partnerships among government bodies, nongovernmental organizations, and the private sector are crucial for mobilizing resources, expertise, and technologies to effectively address the plastic waste crisis.

2.1. The Role of Artificial Intelligence in Waste Management

The application of artificial intelligence (AI) in waste management signifies a significant change in how communities tackle the issues of waste production, collection, sorting, and recycling. Technologies like machine learning, computer vision, and predictive analytics within AI provide creative solutions to enhance waste management operations, improving their overall efficiency and effectiveness. By utilizing extensive data and sophisticated algorithms, AI has the potential to transform waste management methods, leading to decreased environmental repercussions, conservation of resources, and improved sustainability [6].

A key use of AI in waste management involves optimizing waste collection. Conventional waste collection methods typically adhere to fixed schedules and routes, resulting in inefficiencies and wasted resources. AI algorithms can examine past data regarding waste production patterns, population density, and traffic conditions to dynamically improve collection routes in real time. [22]. For instance, Waste Management Inc., a prominent waste management firm in the U.S., employs AI-based route optimization software to enhance its collection processes, yielding notable cost savings and environmental advantages [23].

Additionally, AI-enhanced technologies can improve the sorting and recycling of waste materials, elevating both the quality and quantity of recyclable materials while decreasing contamination levels. Automated sorting systems that incorporate AI algorithms can accurately identify and separate various types of recyclables swiftly, replacing the often tedious and error-prone manual sorting [24]. For example, AMP Robotics, based in Colorado, has created robotic systems that utilize computer vision and machine learning to separate recyclable materials from mixed waste with unparalleled accuracy [25]. Alongside optimizing waste collection and sorting, AI can promote the establishment of smart waste management systems that support real-time monitoring and analysis of waste generation, composition, and disposal trends. IoT (Internet of Things) sensors placed in waste bins and collection vehicles can gather data on fill levels, temperature, and humidity, offering valuable insights for route optimization, capacity planning, and resource distribution[25]. Cities such as Barcelona, Spain, have adopted IoT-enabled smart waste management systems that utilize AI algorithms to refine waste collection routes, lower collection expenses, and lessen environmental impact [26].

Moreover, AI technologies can significantly enhance the efficiency of waste-to-energy (WtE) and landfill management operations. Predictive analytics driven by AI can anticipate energy output from waste-to-energy (WtE) facilities, optimize combustion procedures, and reduce greenhouse gas and air pollutant emissions [27]. Similarly, AI algorithms can streamline landfill management by forecasting waste decomposition rates, detecting potential environmental hazards, and suggesting approaches for landfill site rehabilitation and closure [28]. However, incorporating AI into waste management does face certain challenges and constraints. Technical issues, including data interoperability, privacy concerns, and cybersecurity, present major obstacles to developing and implementing AI technologies in waste management [13][29]. Furthermore, the high initial investment associated with AI adoption and the necessity for specialized knowledge can hinder the uptake of these solutions, especially in resource-limited environments [30]. Additionally, issues related to algorithm bias and ethical concerns must be tackled to ensure the responsible and fair application of AI in waste management [31].

2.2. AI Technologies for Plastic Waste Reduction in Developing Countries

Implementing artificial intelligence technologies provides significant opportunities for tackling plastic waste reduction in developing nations such as Nigeria. In particular, a variety of AI-driven solutions can be utilized to confront this urgent environmental issue. One key application area is the development of intelligent waste management systems, which use AI algorithms and sensor technologies to enhance waste collection routes, forecast waste generation patterns, and boost overall operational efficiency [32]. These systems promote the proactive upkeep of waste infrastructure and allow for more targeted and effective collection efforts, which ultimately reduce costs and improve resource allocation [33]. Additionally, computer vision technology shows considerable promise for automating the sorting of recyclable materials, including plastics, at recycling centers. By applying AI algorithms to evaluate images of waste materials taken by cameras, this technology can correctly categorize materials based on their composition, color, and shape, leading to higher recycling rates and better material quality [34].

Moreover, AI-powered mobile applications offer a valuable method to motivate and reward individuals for recycling plastic waste [7]. These applications implement AI algorithms to monitor recycling activities, provide tailored feedback, and offer incentives such as discounts or virtual points that can be exchanged for products or services, thus encouraging community participation in waste reduction initiatives [7]. Predictive analytics algorithms are also essential for enhancing waste management strategies by examining historical data on waste generation, collection, and disposal to anticipate future trends [6]. By utilizing AI-driven predictive models, municipal authorities can forecast peak demand periods, allocate resources more efficiently, and adopt proactive measures to avert waste buildup and environmental degradation [35].

Furthermore, the use of AI-equipped drones with cameras and sensors has the potential to transform the monitoring and cleanup of plastic waste in hard-to-reach or remote locations [36]. These drones enable aerial surveillance of sites with waste accumulation, detection of illegal dumping activities, and focused cleanup operations [6]. By analyzing images captured by drones with AI algorithms, authorities can prioritize cleanup actions and optimize resource deployment for waste management efforts [37]. Overall, the implementation of these AI technologies presents innovative and effective strategies to combat plastic waste reduction in developing countries like Nigeria, with the potential to significantly lessen the environmental and socio-economic repercussions of plastic pollution [38]. Nonetheless, achieving successful implementation demands collaboration among government agencies, private sector participants, academic institutions, and civil society groups to address technical, regulatory, and socio-economic challenges. [39].

3. Theoretical Exposition: Technology Acceptance Model (TAM)

One appropriate theoretical framework for examining the role of AI in mitigating global plastic waste pollution is the Technology Acceptance Model (TAM). Formulated by Davis in the 1980s, TAM asserts that perceived ease of use and perceived usefulness are critical factors determining an individual's intention to adopt new technology. [40]. Concerning the reduction of plastic waste worldwide, TAM can be utilized to explore the elements that affect the acceptance and integration of AI-based waste management technologies by various stakeholders, including governmental bodies, waste management organizations, industry representatives, and the general public.

According to TAM, individuals tend to embrace technology if they find it user-friendly and believe it will enhance their performance or results [40]. In this regard, stakeholders' views on the ease of use and benefits of AI-driven waste management technologies will impact their readiness to adopt and apply them. Aspects such as user interface design, accessibility, and compatibility with current waste management practices will influence stakeholders' perceptions of ease of use. Simultaneously, the potential advantages related to efficiency improvements, cost reductions, and environmental impact mitigation will shape their views on usefulness.

3.1. Leveraging AI Technologies for Plastic Waste Reduction in Developing Countries

Utilizing artificial intelligence (AI) technologies to reduce plastic waste on a global scale represents a groundbreaking strategy to tackle the urgent environmental issue of plastic pollution. The increasing amount of plastic waste poses threats to ecosystems, public health, and economic well-being, necessitating the development of innovative solutions to lessen its effects. AI presents a valuable opportunity to improve waste management methods through insights derived from data, automation, and optimization. By applying AI technologies, we can transform the approach to plastic waste reduction, promoting a cleaner and more sustainable environment.

One significant application of AI in decreasing plastic waste is in refining waste collection systems. Conventional waste collection techniques frequently suffer from inefficiencies and lack of accuracy, resulting in resource wastage. In contrast, AI-enhanced systems can process large datasets—such as population density, consumption trends, and traffic patterns—to optimize the routes and timing of waste collection. [7].

Additionally, AI-driven sorting technologies show great potential for enhancing the efficiency and precision of plastic waste recycling. Traditional recycling plants typically depend on manual sorting, which is laborious and susceptible to mistakes. AI-enabled sorting systems, utilizing machine learning algorithms and computer vision technology, can precisely identify and separate different plastic types based on characteristics like composition, color, and shape. [7]. This leads to improved sorting accuracies and higher-quality recycled materials, which increases their market value. For example, AI-based sorting machines at recycling facilities worldwide can automatically distinguish PET bottles from other plastics, thereby boosting recycling efficiency and lowering contamination levels. [6].

Moreover, AI is instrumental in monitoring and managing plastic waste pollution in aquatic environments such as Nigeria's rivers and coastal regions. The integration of remote sensing technologies with AI algorithms allows for the analysis of satellite imagery to identify and monitor the accumulation of plastic waste in bodies of water. [7]. By pinpointing areas heavily affected by plastic pollution, authorities can focus clean-up efforts and undertake targeted strategies to curb additional contamination. Furthermore, AI-equipped drones, outfitted with cameras and sensors, can survey water bodies and coastal regions, detecting and collecting floating plastic waste. [2]. These autonomous systems efficiently cover large territories quickly, enhancing traditional clean-up operations while minimizing the environmental effects of plastic waste on aquatic ecosystems.

Furthermore, AI technologies can promote public involvement and change behaviors aimed at reducing plastic use and advancing recycling practices. Social media and mobile applications leveraging AI algorithms can send personalized communications and incentives to motivate people to adopt more sustainable habits[7]. For instance, AI-driven applications can provide immediate feedback on recycling behaviors, monitor progress toward waste reduction objectives, and offer rewards for eco-friendly initiatives [7]. By using AI to engage and empower the public, Nigeria can cultivate a culture of environmental responsibility and collaborative action to reduce plastic waste.

In summary, the application of AI technologies for global plastic waste reduction presents significant potential for revolutionizing waste management practices and promoting a cleaner, more c. Through the optimization of waste collection procedures, enhancement of recycling efficiency, monitoring of plastic pollution in water bodies, and engaging the public in behavior change initiatives, AI can make a crucial contribution to alleviating the impact of plastic waste on ecosystems, public health, and economic welfare. Nevertheless, unlocking the full capabilities of AI in waste management requires cooperation among government entities, industry players, research institutions, and civil society organizations.

4. Challenges and Opportunities in Implementing AI Solutions for Waste Management

Implementing AI technologies in waste management offers both challenges and possibilities, especially in developing countries. While AI solutions present encouraging prospects for improving waste management methods, several barriers must be overcome to fully harness their benefits. A key challenge is the insufficient infrastructure and resources necessary for integrating AI into waste management systems. In most developing countries like the United State of America, restricted financial support[41], technical know-how and access to cutting-edge technologies impede the uptake of AI-enhanced solutions[42] . Additionally, the substantial upfront expenses related to AI implementation, including acquiring equipment, software development, and training, create financial obstacles for many local governments and waste management organizations. Furthermore, the digital divide deepens inequalities in access to AI technologies, with rural regions and disadvantaged communities encountering more significant difficulties in utilizing AI-driven waste management solutions [7].

In addition, data scarcity and quality concerns pose major challenges to effectively deploying AI in waste management. In developing countries, the lack of accessible data, particularly regarding waste generation, composition, and disposal trends, hampers the creation of precise predictive models and decision-making algorithms [6]. Additionally, inconsistencies and variability in data across various regions complicate efforts to standardize AI applications in waste management nationally[43]. Tackling these data-related issues necessitates investments in data collection infrastructure, capacity building, and collaboration among government bodies, academic institutions, and the private sector [43].

Moreover, issues around data privacy, security, and ethical considerations present substantial challenges to the responsible and equitable use of AI in waste management. In developing countries, insufficient regulatory frameworks and data protection measures expose individuals and communities to the dangers associated with the misuse and exploitation of personal information [44]. Additionally, biases in algorithms and discrimination may worsen current disparities in access to waste management services and resources, particularly affecting marginalized and vulnerable groups [45]. Addressing these challenges requires the formulation of strong regulatory frameworks, ethical guidelines, and accountability measures to ensure transparency, fairness, and responsibility in AI-driven waste management projects [46].

Despite these obstacles, the adoption of AI solutions for waste management in Nigeria provides numerous prospects for innovation, efficiency, and sustainability. AI technologies can improve the efficiency and effectiveness of waste collection, sorting, and recycling processes, resulting in cost reductions, resource preservation, and environmental advantages [47]. For instance, AI-powered predictive analytics can optimize waste collection routes and schedules, minimizing fuel consumption, emissions, and operational expenses for waste management agencies [48]. Furthermore, AI-enhanced sorting systems can elevate the quality and quantity of recycled materials, boosting their market value and fostering a circular economy [49].

Additionally, AI technologies can support real-time monitoring and management of waste streams, allowing authorities to more effectively identify and respond to environmental hazards and public health threats [50]. For example, AI-driven sensors and drones can monitor illegal dumping, pinpoint pollution hotspots, and assist in targeted enforcement actions to tackle environmental offenses [2]. Moreover, AI algorithms can evaluate social media data and citizen reports to glean insights into community attitudes, perceptions, and behaviors regarding waste management, informing the development and execution of customized interventions and public awareness initiatives [46].

4.1. Case Studies and Success Stories: AI Applications in Plastic Waste Reduction

Case studies and success stories are plentiful in the field of AI applications aimed at reducing plastic waste, highlighting the transformative capacity of technology in tackling the global environmental issue of plastic pollution. Both advanced and developing nations have adopted AI-driven approaches to improve waste management methods, support recycling efforts, and lessen the effects of plastic waste on ecosystems and communities. A prominent example is Amsterdam in the Netherlands, where AI-equipped smart waste bins have been introduced to enhance the efficiency of waste collection routes and schedules. These smart bins, which are outfitted with sensors and machine learning algorithms, can monitor how full they are and anticipate waste production trends, allowing for more efficient and focused collection operations [51]. By utilizing AI technologies, Amsterdam has realized substantial decreases in waste collection expenses, vehicle emissions, and overall environmental impact, showcasing the benefits of data-informed decision-making in waste management.

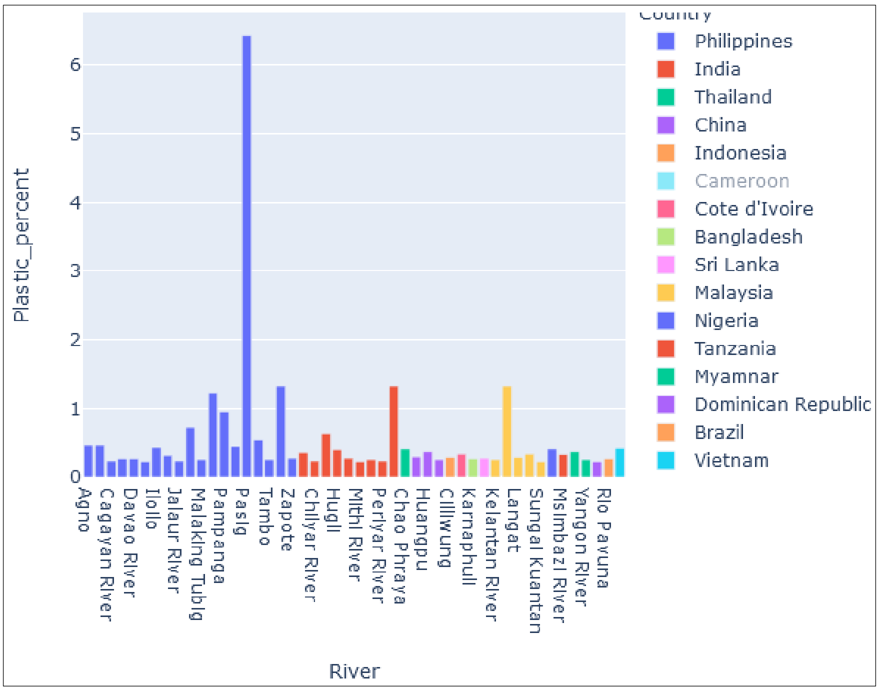

Figure 3 Bar chart of Rivers against the global plastic percentage

Figure 3 above depicts the unusually high percentage composition of plastic pollution in the Pasig River of the Philippines. It points out that there is a severe plastic pollution problem in this river. Equally highly polluted with plastic are the Ganga and Yamuna rivers of India; these, too, are an issue to be paid urgent attention in India. In Thailand, the Chao Phraya River has a moderate level of plastic pollution, hence requiring better waste management. The Huangpu River in China has a relatively low level of plastic pollution compared to other rivers represented in this chart. That might be due to various factors, including but not limited to stricter regulations and improved waste management practices. The two Indonesian rivers, Cilliwung and Citarum, hold a middle position concerning plastic pollution, and more efforts need to be taken to reduce plastic waste in these rivers. The remaining countries on the chart represent those where conditions concerning the plastic pollution of the rivers are different. These range from low in Cameroon, Cote d'Ivoire, Bangladesh, Sri Lanka, Malaysia, Nigeria, Tanzania, Myanmar, Dominican Republic, Brazil, and Vietnam, to moderate.

Many of the rivers with high plastic pollution levels are located in countries with inadequate waste management systems. This leads to improper disposal of plastic waste, which eventually finds its way into rivers. Rivers located in densely populated areas or regions with significant industrial activity are more likely to be polluted with plastic waste.

A lack of implementation of an AI-driven monitoring and recycling system about the harmful effects of plastic pollution and the importance of proper waste disposal can contribute to high levels of plastic pollution in rivers.

In a similar vein, Singapore—known for its high population density and ambitious sustainability objectives—has employed AI-driven recycling systems to boost the efficiency and efficacy of waste sorting operations. By leveraging computer vision technology and machine learning algorithms, recycling facilities in Singapore can autonomously recognize and segregate different types of plastics, metals, and paper products, leading to increased recycling rates and lower contamination levels [52]. This AI-oriented strategy has empowered Singapore to improve its recycling infrastructure, decrease the volume of waste sent to landfills, and foster a circular economy, positioning the city as a global frontrunner in sustainable waste management practices.

In developing nations, AI initiatives aimed at reducing plastic waste have also shown encouraging outcomes, albeit with distinct challenges and opportunities. For example, in Kenya, an innovative program called Mr. Green Africa leverages AI-powered mobile applications to incentivize and reward citizens for recycling plastic materials. Users can scan barcodes on plastic products through the app and earn points that can be exchanged for cash or discounts at participating merchants [53]. This creative solution not only motivates the public to engage in recycling activities but also generates valuable data insights regarding consumer habits and waste production patterns, which can guide targeted measures and policy formulations to combat plastic pollution. Additionally, in Nigeria, where plastic waste presents significant environmental and public health issues, AI technologies are being utilized to enhance waste management techniques and encourage recycling initiatives. In Lagos, Africa's most populous city, AI-equipped drones with cameras and sensors are deployed to survey and monitor water bodies, detecting and collecting floating plastic debris [54]. By applying AI for real-time environmental oversight and management, Lagos authorities can pinpoint pollution hotspots, track illegal dumping, and implement targeted measures to lessen the effects of plastic waste on aquatic ecosystems and coastal communities.

These case studies and success stories highlight the transformative potential of AI applications in reducing plastic waste, cutting across geographical and socioeconomic boundaries. Whether in developed cities like Amsterdam and Singapore or emerging economies like Kenya and Nigeria, AI-driven innovations provide unique solutions to the intricate challenges of plastic pollution, promoting sustainability and environmental responsibility. Nonetheless, to fully harness the potential of AI in waste management, it is essential to tackle technical, regulatory, and social challenges while encouraging collaboration and knowledge exchange among stakeholders. By leveraging the power of technology and collective effort, nations worldwide can work toward a cleaner, greener future where plastic pollution is reduced, and ecosystems flourish.

4.2. Potential Costs and Benefits of implementing AI technologies for Plastic waste reduction in developing countries

Integrating AI technologies to reduce plastic waste in developing nations involves both potential expenses and advantages that need careful evaluation. Firstly, considerable initial investments are needed to develop and launch these technologies, which include costs for procuring AI technology, building infrastructure, and training staff [6]. In addition, obstacles related to technology adoption, such as a lack of technical expertise and infrastructural limitations, may hinder advancement in certain areas [55]. Furthermore, gathering and processing large amounts of data essential for AI systems can be resource-demanding and requires collaboration among various stakeholders [56]. Additionally, operating AI systems may involve significant energy use, which could exacerbate issues in regions with limited access to stable energy resources [57]. On the other hand, the introduction of AI technologies presents encouraging benefits. These advantages include improved efficiency in waste management through optimized collection routes and enhanced sorting processes, which may lead to cost reductions and better resource use[58]. Moreover, AI-based sorting systems can boost recycling rates by precisely separating materials, thereby decreasing dependency on landfills and reducing environmental contamination [48]. By lessening the environmental repercussions of plastic waste, these technologies aid in preserving ecosystems and safeguarding human health [59]. Additionally, the application of AI solutions can generate new economic opportunities and promote innovation, which in turn can lead to job creation and economic advancement[60]. Although the initial expenses may be high, the long-term advantages, such as enhanced waste management efficiency, environmental protection, and economic development, highlight the potential transformative effect of AI in tackling the intricate issue of plastic waste in developing nations.

4.3. Ethical Considerations in the Implementation of AI Technologies for Waste Management

Ethical considerations are vital in the deployment of AI technologies within waste management, ensuring that these technologies are utilized responsibly and fairly. A crucial element is the necessity for transparency and accountability regarding AI algorithms and their decision-making processes. This requires offering clear insights into the functioning of AI systems, detailing how they gather, process, and analyze data, along with the methods employed to make decisions or suggestions. Transparency fosters trust among stakeholders and facilitates the scrutiny of AI systems, allowing for the identification and correction of any biases or inaccuracies that may occur[61].

Another significant ethical concern is the principle of fairness and the avoidance of discrimination in AI applications. AI algorithms must be crafted and trained to prevent the continuation or worsening of existing biases or disparities, especially for marginalized or vulnerable groups. Achieving fairness can involve the collection of varied and inclusive data, thorough bias testing, and the continuous monitoring and assessment of AI systems in practical settings[62]. Furthermore, privacy and data protection are critical ethical issues in AI-focused waste management. Personal data that AI systems collect and process must be managed securely and in compliance with applicable privacy laws and best practices. This entails implementing strong data protection strategies, securing informed consent from individuals whose data is utilized, and anonymizing or de-identifying data whenever feasible to safeguard privacy [38].

Appendix

- plastic=pd.read_csv('/kaggle/input/plastic-input-into-worlds-oceans/plastics-top-rivers.csv')
- plastic.head()
- plastic.info()
- # checking for null values
- plastic.isnull().sum()
- # total number of countries
- plastic['Country'].nunique()
- # top 5 countries with highest share of global plastics emitted to ocean in %
- df1.sort_values('sharePlastics',ascending=False).head(5)
- colors = ['lightskyblue', 'red', 'blue', 'green', 'gold','aqua','purple','orange']
- df1.sharePlastics.plot.pie(autopct='%1.2f%%',figsize=(8,8), label='emission', colors=colors)
- plt.show()
- fig = px.bar(River_Total, x=River_Total.index, y="river_total")
- fig.show()
- fig = px.bar(df,x='River',y='Plastic_percent',color='Country')
- fig.show()

5. Conclusion

The potential for AI-driven plastic waste reduction in developing nations is substantial and could lead to significant changes. As the global community faces the pressing need to tackle plastic pollution—especially in areas with inadequate waste management systems and severe environmental challenges—AI technologies present groundbreaking solutions to improve waste management methods, lessen environmental harm, and foster sustainable growth. A crucial factor influencing the future of AI-driven plastic waste reduction in developing countries is the ongoing progress and implementation of AI technologies.

Mechanisms for accountability should be put in place to ensure that those involved in the development, implementation, and management of AI technologies in waste management can be held responsible for their actions and decisions. This could include establishing clear lines of accountability, outlining processes for addressing complaints or issues related to AI systems, and creating oversight bodies or regulatory frameworks to ensure adherence to ethical standards Lastly, continuous ethical reflection and engagement with stakeholders are crucial for navigating the intricate ethical dilemmas associated with AI in waste management. This entails promoting dialogue among varied stakeholders, such as community members, policymakers, industry representatives, and ethicists, to pinpoint and tackle emerging ethical challenges, cultivate shared norms and values, and ensure that AI technologies align with broader societal aspirations and principles.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Damilola Victoria Awe, Tesleem Babatunde Asafa, Taiwo Adebowale Adeniran, Peter Efosa Ohenhen, Victoria Adebisi Alao, and Olusegun Abiodun Balogun, 'Development and performance evaluation of a mini plastic crushing machine', *World Journal of Advanced Research and Reviews*, vol. 22, no. 1, pp. 591–602, Apr. 2024, doi: 10.30574/wjarr.2024.22.1.1126.

[2] J. R. Jambeck *et al.*, 'Plastic waste inputs from land into the ocean', *Science (1979)*, vol. 347, no. 6223, pp. 768–771, Feb. 2015, doi: 10.1126/science.1260352.

[3] R. Geyer, J. R. Jambeck, and K. L. Law, 'Production, use, and fate of all plastics ever made', *Sci Adv*, vol. 3, no. 7, Jul. 2017, doi: 10.1126/sciadv.1700782.

[4] S. Oludele, A. Samuel, and O. Omosat, 'Unveiling environmental governance and political economy dynamics in rural plastic pollution management: a case study of Ogun State, Nigeria', *Reality of Politics*, vol. 25, no. 3, pp. 74–113, Sep. 2023, doi: 10.15804/rop2023305.

[5] A. Sabharwal and B. Selman, 'Book review', *Artif Intell*, vol. 175, no. 5–6, pp. 935–937, Apr. 2011, doi: 10.1016/j.artint.2011.01.005.

[6] J. Tang, T. Wang, H. Xia, and C. Cui, 'An Overview of Artificial Intelligence Application for Optimal Control of Municipal Solid Waste Incineration Process', Jan. 24, 2024. doi: 10.20944/preprints202401.1718.v1.

[7] O. M. Solaja, 'Unleashing the Power of AI: Revolutionizing Plastic Waste Management for Sustainable Development in Developing Nations', *Oludele Mayowa Solaja 28 Waste Technology*, vol. 12, no. 1, pp. 28–38, 2024, doi: 10.14710/wastech.12.1.28-38.

[8] 'Politecnico di Torino Artificial Intelligence applications in Reverse Logistics'.

[9] S. Das, S.-H. Lee, P. Kumar, K.-H. Kim, S. S. Lee, and S. S. Bhattacharya, 'Solid waste management: Scope and the challenge of sustainability', *J Clean Prod*, vol. 228, pp. 658–678, Aug. 2019, doi: 10.1016/j.jclepro.2019.04.323.

[10] T. A. Kurniawan, C. Meidiana, M. H. Dzarfan Othman, H. H. Goh, and K. W. Chew, 'Strengthening waste recycling industry in Malang (Indonesia): Lessons from waste management in the era of Industry 4.0', *J Clean Prod*, vol. 382, p. 135296, Jan. 2023, doi: 10.1016/j.jclepro.2022.135296.

[11] B. Fang *et al.*, 'Artificial intelligence for waste management in smart cities: a review', *Environ Chem Lett*, vol. 21, no. 4, pp. 1959–1989, Aug. 2023, doi: 10.1007/s10311-023-01604-3.

[12] I. Omondi and M. Asari, 'Impact of Policy Design on Plastic Waste Reduction in Africa', *Sustainability (Switzerland)*, vol. 16, no. 1, Jan. 2024, doi: 10.3390/su16010004.

[13] Olakunle Abayomi Ajala and Olusegun Abiodun Balogun, 'Leveraging AI/ML for anomaly detection, threat prediction, and automated response', *World Journal of Advanced Research and Reviews*, vol. 21, no. 1, pp. 2584–2598, Jan. 2024, doi: 10.30574/wjarr.2024.21.1.0287.

[14] S. Subramaniam *et al.*, 'Artificial Intelligence Technologies for Forecasting Air Pollution and Human Health: A Narrative Review', *Sustainability*, vol. 14, no. 16, p. 9951, Aug. 2022, doi: 10.3390/su14169951.

[15] A. Adel and N. HS Alani, 'Human-Centric Collaboration and Industry 5.0 Framework in Smart Cities and Communities: Fostering Sustainable Development Goals 3, 4, 9, and 11 in Society 5.0', *Smart Cities*, vol. 7, no. 4, pp. 1723–1775, Jul. 2024, doi: 10.3390/smartcities7040068.

[16] Metz Cynthia Eugenie Konan, 'Public health implications of plastic pollution: Reducing national healthcare burden', *World Journal of Advanced Research and Reviews*, vol. 24, no. 1, pp. 1755–1763, Oct. 2024, doi: 10.30574/wjarr.2024.24.1.3181.

[17] B. Yalwaji, H. O. John-Nwagwu, and T. O. Sogbanmu, 'Plastic pollution in the environment in Nigeria: A rapid systematic review of the sources, distribution, research gaps and policy needs', *Sci Afr*, vol. 16, p. e01220, Jul. 2022, doi: 10.1016/j.sciaf.2022.e01220.

[18] R. Verma, K. S. Vinoda, M. Papireddy, and A. N. S. Gowda, 'Toxic Pollutants from Plastic Waste- A Review', *Procedia Environ Sci*, vol. 35, pp. 701–708, 2016, doi: 10.1016/j.proenv.2016.07.069.

[19] G. Uchechukwu Nwafor, 'Impact of Plastic Pollution on the Economic Growth and Sustainability of Blue Economy in Nigeria', *African Journal of Environment and Natural Science Research*, vol. 7, no. 1, pp. 113–127, Feb. 2024, doi: 10.52589/AJENSR-HHV6SBJF.

[20] S. P, 'Nigeria's E-Waste Management: Extended Producer Responsibility and Informal Sector Inclusion', *Journal of Waste Resources and Recycling*, vol. 1, no. 1, pp. 1–9, Aug. 2019, doi: 10.15744/2766-5887.1.102.

[21] A. E. Adeniran, A. T. Nubi, and A. O. Adelopo, 'Solid waste generation and characterization in the University of Lagos for a sustainable waste management', *Waste Management*, vol. 67, pp. 3–10, Sep. 2017, doi: 10.1016/j.wasman.2017.05.002.

[22] N. V Karadimas, K. Papatzelou, and V. G. Loumos, 'Genetic Algorithms for Municipal Solid Waste Collection and Routing Optimization'.

[23] L. Andeobu, S. Wibowo, and S. Grandhi, 'Artificial intelligence applications for sustainable solid waste management practices in Australia: A systematic review', *Science of The Total Environment*, vol. 834, p. 155389, Aug. 2022, doi: 10.1016/j.scitotenv.2022.155389.

[24] O. Sarkar, A. Dey, and T. Malik, 'Modernized Management of Biomedical Waste Assisted with Artificial Intelligence', *International Journal of Biomedical and Clinical Analysis*, vol. 3, no. 2, pp. 69–86, Dec. 2023, doi: 10.61797/ijbca.v3i2.265.

[25] P. Ramya, R. V, and B. R. M, 'E-waste management using hybrid optimization-enabled deep learning in IoT-cloud platform', *Advances in Engineering Software*, vol. 176, p. 103353, Feb. 2023, doi: 10.1016/j.advengsoft.2022.103353.

[26] Md. A. Rahman, S. W. Tan, A. Taufiq Asyhari, I. F. Kurniawan, M. J. F. Alenazi, and M. Uddin, 'IoT-Enabled Intelligent Garbage Management System for Smart City: A Fairness Perspective', *IEEE Access*, vol. 12, pp. 82693–82705, 2024, doi: 10.1109/ACCESS.2024.3412098.

[27] D. Shin, J. Lee, J. Son, Y. Yun, Y. Song, and J. Song, 'Intelligent Combustion Control in Waste-to-Energy Facilities: Enhancing Efficiency and Reducing Emissions Using AI and IoT', *Energies (Basel)*, vol. 17, no. 18, p. 4634, Sep. 2024, doi: 10.3390/en17184634.

[28] J. Tao *et al.*, 'Intelligent technologies powering clean incineration of municipal solid waste: A system review', *Science of The Total Environment*, vol. 935, p. 173082, Jul. 2024, doi: 10.1016/j.scitotenv.2024.173082.

[29] K. Wang, Y. Zhao, R. K. Gangadhari, and Z. Li, 'Analyzing the Adoption Challenges of the Internet of Things (IoT) and Artificial Intelligence (AI) for Smart Cities in China', *Sustainability*, vol. 13, no. 19, p. 10983, Oct. 2021, doi: 10.3390/su131910983.

[30] F. Sukums *et al.*, 'The use of artificial intelligence-based innovations in the health sector in Tanzania: A scoping review', *Health Policy Technol*, vol. 12, no. 1, p. 100728, Mar. 2023, doi: 10.1016/j.hlpt.2023.100728.

[31] H. Roberts *et al.*, 'Artificial intelligence in support of the circular economy: ethical considerations and a path forward', *AI Soc*, vol. 39, no. 3, pp. 1451–1464, Jun. 2024, doi: 10.1007/s00146-022-01596-8.

[32] H. Roberts *et al.*, 'Artificial intelligence in support of the circular economy: ethical considerations and a path forward', *AI Soc*, vol. 39, no. 3, pp. 1451–1464, Jun. 2024, doi: 10.1007/s00146-022-01596-8.

[33] R. Rehan, M. A. Knight, A. J. A. Unger, and C. T. Haas, 'Financially sustainable management strategies for urban wastewater collection infrastructure – development of a system dynamics model', *Tunnelling and Underground Space Technology*, vol. 39, pp. 116–129, Jan. 2014, doi: 10.1016/j.tust.2012.12.003.

[34] C. Araujo-Andrade *et al.*, 'Review on the photonic techniques suitable for automatic monitoring of the composition of multi-materials wastes in view of their posterior recycling', *Waste Management & Research: The Journal for a Sustainable Circular Economy*, vol. 39, no. 5, pp. 631–651, May 2021, doi: 10.1177/0734242X21997908.

[35] 'THE MODERN VECTOR OF THE DEVELOPMENT OF SCIENCE Proceedings of the XVI International Scientific and Practical Conference', doi: 10.5281/zenodo.13929032.

[36] 'The World Setting History General Planets and Life', 1999. [Online]. Available: http://www.nada.kth.se/~asa/Game/BigIdeas/player.html

[37] M. Farghali and A. I. Osman, 'Revolutionizing waste management: unleashing the power of artificial intelligence and machine learning', in *Advances in Energy from Waste*, Elsevier, 2024, pp. 225–279. doi: 10.1016/B978-0-443-13847-8.00007-5.

[38] S. J. Russell *et al.*, 'Artificial Intelligence A Modern Approach Third Edition'.

[39] S. Waddell, *Societal Learning and Change*. Routledge, 2017. doi: 10.4324/9781351280761.

[40] F. D. Davis, 'Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology', *MIS Quarterly*, vol. 13, no. 3, p. 319, Sep. 1989, doi: 10.2307/249008.

[41] Jodian Campbell and Boris A Koffi, 'The Role of AI-powered financial analytics in shaping economic policy: A new era for risk management and national growth in the United States', *World Journal of Advanced Research and Reviews*, vol. 23, no. 3, pp. 2816–2825, Sep. 2024, doi: 10.30574/wjarr.2024.23.3.2963.

[42] J. Bughin *et al.*, 'ARTIFICIAL INTELLIGENCE THE NEXT DIGITAL FRONTIER?' [Online]. Available: www.mckinsey.com/mgi.

[43] R. He *et al.*, 'Global knowledge base for municipal solid waste management: Framework development and application in waste generation prediction', *J Clean Prod*, vol. 377, p. 134501, Dec. 2022, doi: 10.1016/j.jclepro.2022.134501.

[44] M. Sepulveda, 'Is biometric technology in social protection programmes illegal or arbitrary? An analysis of privacy and data protection', 2018. [Online]. Available: www.ilo.org/publns.

[45] B. A. Williams, C. F. Brooks, and Y. Shmargad, 'How Algorithms Discriminate Based on Data They Lack: Challenges, Solutions, and Policy Implications', *Journal of Information Policy*, vol. 8, pp. 78–115, Mar. 2018, doi: 10.5325/jinfopoli.8.2018.0078.

[46] S. Zhang, H.-L. Wei, and J. Ding, 'An effective zero-shot learning approach for intelligent fault detection using 1D CNN', doi: 10.1007/s10489-022-04342-1/Published.

[47] L. Andeobu, S. Wibowo, and S. Grandhi, 'Artificial intelligence applications for sustainable solid waste management practices in Australia: A systematic review', *Science of The Total Environment*, vol. 834, p. 155389, Aug. 2022, doi: 10.1016/j.scitotenv.2022.155389.

[48] D. B. Olawade *et al.*, 'Smart waste management: A paradigm shift enabled by artificial intelligence', *Waste Management Bulletin*, vol. 2, no. 2, pp. 244–263, Jun. 2024, doi: 10.1016/j.wmb.2024.05.001.

[49] Z. Farshadfar, T. Mucha, and K. Tanskanen, 'Leveraging Machine Learning for Advancing Circular Supply Chains: A Systematic Literature Review', *Logistics*, vol. 8, no. 4, p. 108, Oct. 2024, doi: 10.3390/logistics8040108.

[50] S. M. Popescu *et al.*, 'Artificial intelligence and IoT driven technologies for environmental pollution monitoring and management', *Front Environ Sci*, vol. 12, Feb. 2024, doi: 10.3389/fenvs.2024.1336088.

[51] M. T. Munir, B. Li, and M. Naqvi, 'Revolutionizing municipal solid waste management (MSWM) with machine learning as a clean resource: Opportunities, challenges and solutions', *Fuel*, vol. 348, p. 128548, Sep. 2023, doi: 10.1016/j.fuel.2023.128548.

[52] P. Kerdlap, J. S. C. Low, and S. Ramakrishna, 'Zero waste manufacturing: A framework and review of technology, research, and implementation barriers for enabling a circular economy transition in Singapore', *Resour Conserv Recycl*, vol. 151, p. 104438, Dec. 2019, doi: 10.1016/j.resconrec.2019.104438.

[53] J. Lauer, 'Plastic surveillance: Payment cards and the history of transactional data, 1888 to present', *Big Data Soc*, vol. 7, no. 1, p. 205395172090763, Jan. 2020, doi: 10.1177/2053951720907632.

[54] S. Kandrot and P. Holloway, 'Work Package 2: Technological Innovation for Sustainable Development Deliverable T2.1.1: Project report Applications of Drone Technology for Sustainable Development of the Coastal Zone: A Literature Review', 2020.

[55] C. R. Doss, 'Analyzing technology adoption using microstudies: limitations, challenges, and opportunities for improvement', *Agricultural Economics*, vol. 34, no. 3, pp. 207–219, May 2006, doi: 10.1111/j.1574-0864.2006.00119.x.

[56] R. Souza *et al.*, 'Workflow Provenance in the Computing Continuum for Responsible, Trustworthy, and Energy-Efficient AI', in *2024 IEEE 20th International Conference on e-Science (e-Science)*, IEEE, Sep. 2024, pp. 1–7. doi: 10.1109/e-Science62913.2024.10678731.

[57] N. M. Kumar *et al.*, 'Distributed Energy Resources and the Application of AI, IoT, and Blockchain in Smart Grids', *Energies (Basel)*, vol. 13, no. 21, p. 5739, Nov. 2020, doi: 10.3390/en13215739.

[58] A. Demirbas, 'Waste management, waste resource facilities and waste conversion processes', *Energy Convers Manag*, vol. 52, no. 2, pp. 1280–1287, Feb. 2011, doi: 10.1016/j.enconman.2010.09.025.

[59] R. Kumar *et al.*, 'Impacts of Plastic Pollution on Ecosystem Services, Sustainable Development Goals, and Need to Focus on Circular Economy and Policy Interventions', *Sustainability*, vol. 13, no. 17, p. 9963, Sep. 2021, doi: 10.3390/su13179963.

[60] E. Ernst, R. Merola, and D. Samaan, 'Economics of Artificial Intelligence: Implications for the Future of Work', *IZA J Labor Policy*, vol. 9, no. 1, Aug. 2019, doi: 10.2478/izajolp-2019-0004.

[61] G. B. Mensah, 'Artificial Intelligence and Ethics: A Comprehensive Review of Bias Mitigation, Transparency, and Accountability in AI Systems', doi: 10.13140/RG.2.2.23381.19685/1.

[62] P. Chen, L. Wu, and L. Wang, 'AI Fairness in Data Management and Analytics: A Review on Challenges, Methodologies and Applications', *Applied Sciences*, vol. 13, no. 18, p. 10258, Sep. 2023, doi: 10.3390/app131810258.

[63] Y. Alahmed, R. Abadla, N. Ameen, and A. Shteiwi, 'Bridging the Gap Between Ethical AI Implementations', *International Journal of Membrane Science and Technology*, vol. 10, no. 3, pp. 3034–3046, Oct. 2023, doi: 10.15379/ijmst.v10i3.2953