

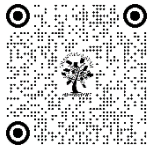


AI FOR SUSTAINABLE DEVELOPMENT: INNOVATIONS & APPLICATIONS

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ABSTRACT

Artificial intelligence (AI) has become universal across various sectors, permeating every aspect of our lives regardless of age or profession. In this era of AI, it's necessary to prioritize sustainable development and innovation in its application. While AI enables rapid completion of tasks alike human efficiency, it also raises concerns about increasing unemployment rates. However, AI serves as a powerful tool for decoding the universe, emphasizing the necessity of sustainable AI development.

This review paper examines the critical role of Artificial Intelligence (AI) in advancing the Sustainable Development Goals (SDGs) across multiple sectors, including healthcare, education, urban planning, agriculture, energy, and environmental conservation. Through the utilization of AI technologies, such as predictive analytics and machine learning algorithms, transformative solutions are being implemented to address complex challenges and facilitate sustainable development. However, challenges such as ethical considerations, data privacy concerns, accessibility issues, and the digital divide must be addressed to ensure equitable and sustainable deployment of AI technologies for SDGs. This paper emphasizes the importance of interdisciplinary collaboration, continued investment, capacity building, and policy frameworks to maximize the positive impact of AI while mitigating potential risks and disparities. By prioritizing ongoing investment in AI for sustainable development, stakeholders can unlock its full potential and pave the way for a sustainable and inclusive future.

Keywords: Sustainable Development Goals (SDGs) & AI Technologies for Sustainable Development.

1. INTRODUCTION

Artificial Intelligence (AI) stands at the forefront of technological innovation, offering unprecedented opportunities for advancing the Sustainable Development Goals (SDGs) across diverse sectors. From healthcare to environmental conservation, AI holds the promise of revolutionizing how we tackle complex challenges and achieve sustainable development. By harnessing AI technologies such as predictive analytics and machine learning algorithms, stakeholders can leverage data-driven insights to drive transformative solutions. However, alongside the potential benefits, there exist critical considerations regarding ethics, privacy, accessibility, and inclusivity that must be addressed to ensure the responsible and equitable deployment of AI for SDGs.

This review paper aims to delve into the critical role of AI in advancing the SDGs, spanning sectors such as healthcare, education, urban planning, agriculture, energy, and environmental conservation. Through an exploration of current research, case studies, and best practices, this paper seeks to elucidate the transformative potential of AI in addressing complex sustainability challenges. Additionally, it will examine the challenges and barriers hindering the widespread adoption of AI for sustainable development.

An overview of the structure is provided, outlining the main sections and themes that will be explored in detail throughout the paper. Through this systematic approach, this review aims to contribute to the growing discourse on AI and sustainable development, providing insights and recommendations for policymakers, researchers, and practitioners alike.

2. SUSTAINABLE DEVELOPMENT GOALS (SDGS)

In the year 2015, 17 sustainable development goals (SDGs) proposed by the United Nations composed of 169 targets for the 2030 United Nations agenda for sustainable development [Nasir et al. (2023)]. The agenda is to transform our world by intercepting various challenges human beings are facing to ensure well-being environmental protection and economic.

Prosperity. They aim to foster well-being, economic prosperity, and environmental conservation worldwide. The SDGs acknowledge that achieving sustainable development requires addressing multiple issues concurrently and understanding the interconnections among them. This entails identifying synergies, where progress in one goal enhances progress in others, as well as trade-offs, where advancement in one area may impede progress in another. Analyzing these interactions helps prioritize actions and policies to maximize positive outcomes and alleviate conflicts. (Nasir, Javed, Gupta, Vinuesa, & Qadir, 2023).

To tackle global challenges, the UN has embraced 17 Sustainable Development Goals (SDGs). Future leaders and stakeholders must recognize the significance of these goals. In this study, we assessed the importance of each SDG among environmental students in 41 countries. Analyzing these evaluations, we categorized the SDGs into three factors reflecting sustainability pillars. These factors vary in importance across nations. We correlated these factors with country-specific metrics like the Human Development Index. Higher-index countries rate SDGs less important than lower-index ones. This offers guidance on promoting SDGs effectively in each country. (Pradhan, Costa, Rybski, Lucht, & Kropp, 2017)

3. AI TECHNOLOGIES FOR SUSTAINABLE DEVELOPMENT

Facing interconnected issues such as poverty, disparity, and climate change, humankind seeks solutions through technology. This section explores the role of artificial intelligence (AI) in the Sustainable Development Goals (SDGs), balancing opportunities and challenges. AI's capabilities in data analysis, trend projection, and resource optimization are evident. It supports SDGs such as eradicating hunger, predicting agricultural yields for SDG 2, and anticipating climate-related events for SDG 13. Additionally, it improves healthcare and education for SDGs 4 and 10. However, AI also presents risks. Data prejudice reinforces inequalities (SDG 5), automation jeopardizes employment (SDG 1), and transparency issues undermine trust (SDG 16). To harness AI's potential, responsible implementation is crucial, prioritizing human-centric approaches. Addressing limitations, capitalizing on strengths, and ethical considerations can harness AI for a positive impact. This section advocates for further exploration of specific AI applications for each SDG, their social and environmental repercussions, and the development of ethical frameworks. (Lajara, Tudela, & Yadav, 2024). AI may act as a facilitator for 134 targets (79%) across all SDGs, primarily through technological improvement, which may allow to overcome certain present limitations. (Pradhan, Costa, Rybski, Lucht, & Kropp, 2017).

According to John McCarthy, the pioneer of AI who coined the term in 1956, said that "AI is the combination of computer science and engineering to create intelligent devices for human welfare. It surpasses human intellect across various fields, such as computer science and linguistics. AI involves machines performing tasks intellectually, touching upon philosophy, mathematics, biology, and sociology. AI showcases intelligent behavior, learning, demonstrating, and advising users. (Patil & Mahind, 2017).

4. ARTIFICIAL INTELLIGENCE METHODS

AI is a field of technology dedicated to developing systems that can perform tasks typically requiring human intelligence. These tasks include learning, reasoning, and problem-solving. Artificial Intelligence (AI) includes machine learning for improving data, deep learning with advanced pattern recognition, and robotics for automating tasks. Natural language

processing aids in understanding human language, while machine vision analyzes images, benefiting sectors from healthcare to digital marketing. These technologies are reshaping industries by automating tasks and enhancing data processing capabilities (Collins, Dennehy, Conboy, & Mikalef, 2021).

- **Machine Learning:** In this AI application, machines acquire skills and enhance performance through experience rather than being explicitly programmed. Deep Learning, a branch of machine learning, utilizes artificial neural networks for predictive analysis. Machine learning encompasses Unsupervised, Supervised, and Reinforcement Learning algorithms, each employing unique methods for data processing and decision-making. (Saini, 2023)
- **Deep Learning:** Deep Learning (DL) has transformed advanced robotics, enhancing intelligence, efficiency, and adaptability. It powers autonomous navigation, object recognition, and collaborative robots. DL also optimizes transportation safety, manufacturing assembly, aviation management, and taxi services, driving productivity in robotics industries (Soori, Arezoo, & Roza, 2023).
- **Neural Networks:** NNs are biologically inspired networks comprising interconnected computational "neurons" arranged in layers. Through weight adjustments, NNs can approximate nearly any nonlinear function with precision. They learn from input-output examples, employing algorithms like backpropagation for supervised learning. (Saini, 2023).
- **Natural Language Processing (NLP):** Natural Language Processing (NLP) involves computer-human language interactions, where machines process human languages. Machine Learning aids NLP in extracting meaning from human speech. NLP applications include IVR (Interactive Voice Response) systems, language translation tools like Google Translate, and grammar checking in word processors. Despite language complexity, NLP algorithms abstract language rules, converting unstructured human language data into machine-understandable formats (Saini, 2023).
- **Machine Vision:** Machines capture and analyze visual data using cameras, analog-to-digital conversion, and digital signal processing. Key aspects of machine vision include sensitivity to weak impulses and resolution for object distinction. Machine vision applications include signature recognition, pattern detection, and medical image analysis (Saini, 2023).
- **Automation & Robotics:** Automation and robotics involve the integration of Artificial Intelligence (AI) to streamline processes and tasks traditionally performed by humans. They encompass technological advancements aimed at enhancing efficiency, productivity, and competitiveness across various industries (Nishar, 2023). This automation can deter fraud during online financial transactions through CAPTCHA technology. Robotic process automation is coded to execute high-volume repetitive tasks and can adjust to varying situations. (Saini, 2023)

5. APPLICATIONS OF AI IN SUSTAINABLE DEVELOPMENT

Our assessment of AI's impact on the Sustainable Development Goals (SDGs) reveals it can benefit 79% of all targets by leveraging technological advancements to overcome current limitations. However, it also poses challenges for 35% of targets. We categorize SDGs into Society, Economy, and Environment pillars. AI shows promise in the Society category, benefiting 82% of its targets such as SDG 1 (No Poverty), SDG 4 (Quality Education), SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), and SDG 11 (Sustainable Cities) by enhancing services and promoting low-carbon initiatives like circular economies and smart cities. Yet, AI's high energy consumption, as seen in activities like cryptocurrency mining, impacts SDG 7 and SDG 13 (Climate Action). Mitigating efforts include improving data center efficiency and promoting renewable energy in ICTs. Integrating human expertise into AI development can reduce energy-intensive processes and address concerns regarding job inequalities related to SDGs 1, 4, and 5 (Gender Equality). Managing AI's potential drawbacks is essential while leveraging its opportunities to advance the 2030 Agenda effectively (Vinuesa, et al., 2020).

- **Healthcare:** AI has revolutionized healthcare across various domains, including medical imaging, virtual patient care, research, patient engagement, rehabilitation, and administrative tasks. Its impact spans from detecting clinical conditions and managing COVID-19 outbreaks to enhancing patient compliance and reducing the workload of healthcare professionals. However, challenges such as privacy, safety, and cost must be addressed through effective governance to ensure patient safety and trust. Despite these hurdles, the integration of AI into healthcare has the potential to meet future healthcare needs (Al Kuwaiti, et al., 2023). This study examines healthcare workers' perceptions and readiness for AI through a web-based questionnaire. Survey shows AI awareness due to limited

formal healthcare training. The majority see AI as beneficial for public health, urging collaborative action for its realization. (Tezpal, Ghosh, Lalwani, Yadav, & Yadav, 2024).

- **Agriculture:** AI enhances contemporary agriculture through precision techniques, predictive analytics, robotics, and market insights, improving production, efficiency, and sustainability. By providing detailed crop, soil, and weather data, AI-driven precision agriculture optimizes resource allocation. Predictive analytics aids in forecasting yields and market dynamics, enhancing strategic planning and resilience. (Mishra, Das, & Awtar, 2024). Intelligent cultivation methods, driven by AI, IoT, and automation, revolutionize food, fiber, and bioenergy production. Smart Agriculture combines AI algorithms and IoT sensor data for real-time monitoring and optimization of farming practices, enhancing crop management, resource allocation, and pest control. (Parashar, Mabrouki, & Sharma, 2024)
- **Energy:** As the global population surpasses eight billion, demand for food, water, and energy surges, especially with advancing technology. However, escalating energy needs, coupled with greenhouse gas emissions from fossil fuels, drive the urgent shift towards renewable energy sources like solar, wind, and hydro, necessitating enhanced efficiency through AI-driven technologies. AI algorithms analyze real-time data from sensors to optimize energy systems, predict power generation, prevent failures, and streamline operations, offering significant time and cost savings (Haklidi, 2021).
- **Environmental Conservation:** AI and robotics are powerful allies in addressing environmental challenges, from safeguarding biodiversity to combating climate change and promoting sustainable development. Technologies like machine learning, computer vision, and natural language processing have transformed environmental monitoring and management. Underwater robots with sensors and cameras assist in exploring and monitoring marine ecosystems, aiding in coral reef restoration and protecting marine species. The integration of AI and robotics goes beyond surveillance to active intervention and restoration efforts, ensuring a better future for generations to come. (Collins A. C., 2024). Research is vital to analyze AI's social, and environmental impacts in Sustainable Development Goals (SDGs). Assessments are needed across healthcare, education, and environmental sectors to inform evidence-based policies, considering diverse stakeholder perspectives for inclusive decision-making (Yadav, Tudela, & Marco-Lajara, 2024).
- **Education:** Increased research on AI in education suggests changing roles for teachers, schools, and leaders. This phenomenological study examines potential scenarios and implications. Findings highlight benefits, drawbacks, and suggestions for AI use. While optimism exists, concerns, especially from educators, persist (Göçen & Aydemir, 2020).
- **Urban Planning:** Artificial intelligence (AI) impacts every perspective of our lives. AI's widespread influence leads to discussions on its impact on urban design and planning, swiftly elevating its significance. Urban design and planning professionals are slowly adopting AI, but big-tech companies are already exploring its potential in niche tasks. There's a growing need to meld creative skills with AI expertise for sustainable urban development, emphasizing citizen participation and exploring how embracing AI could benefit design processes in the future. (Burry, 2022)

6. CHALLENGES AND LIMITATIONS

Challenges and limitations include potential gaps in the literature, subjectivity despite efforts to minimize it, the political compromise nature of SDGs limiting complex dynamics representation, and the need to consider SDGs alongside other international agreements for comprehensive analysis (Vinuesa, et al., 2020).

- **Ethical Considerations:** As artificial intelligence (AI) and deep learning (DL) technologies become more prevalent across different sectors, it is becoming increasingly important to tackle the ethical considerations and privacy issues linked with their utilization. AI models, trained on vast datasets, inherently face the possibility of encoding and perpetuating the biases inherent in the data, potentially resulting in unfair practices. This risk is not just hypothetical; recent research has demonstrated that biases in AI models can have substantial real-world consequences, including exacerbating existing social disparities (Fan, Yan, & Wen, 2007).
- **Technological Limitations:** AI for sustainability faces challenges such as overreliance on historical data, uncertain human responses, cybersecurity risks, adverse impacts, and difficulty in measuring effects, necessitating multilevel, systemic, design-oriented, psychological, sociological, and economic considerations (Nishant, Kennedy, & Corbett, 2020). AI's obstacles in sustainable development (SDGs) include data interpretation challenges, biases perpetuating

inequalities, and energy-intensive processes potentially counteracting sustainability efforts, hindering holistic environmental and social progress.

- Environmental impact of AI technologies: The Impact of AI on the environment identifies potential mitigation strategies and assesses the role of policy. The five major themes that directly impact environmental mitigation are Strategies, Technological Innovations, Public awareness, Policy and regulation, and Engagement. Each theme engirds various categories and concepts, such as Energy Consumption, E-Waste, Renewable Energy Adoption, Sustainable Design, Energy-Efficient Hardware, Legislation and Standards, Educational Campaigns, and Digital Literacy. (Naeeni & Nouhi2, 2023). AI and ML are crucial in climate research, providing unparalleled predictive modeling and assessing environmental effects, aiding understanding and action against climate change. (Hamdan, Ibekwe, Ilojiana, Etukudoh, & Umoh, 2024).

7. FUTURE DIRECTIONS AND OPPORTUNITIES

Agricultural AI innovations could revolutionize farming and food systems, with hyperspectral imaging and drone sensors enhancing crop and soil monitoring. Future agriculture will leverage AI for data-driven, precision crop management, improving yield and sustainability. To ensure equitable access, governments must invest in digital infrastructure, while partnerships should drive research and capacity-building. Regulations should govern ethical AI use and data protection for all stakeholders (Mishra, Das, & Awtar, 2024). The integration of Artificial Intelligence (AI) in agriculture has brought about a significant revolution. AI-powered technologies like automated irrigation, robotic weeding, and sensor-based spraying have addressed challenges such as climate change impacts, population growth, and labor shortages. These innovations not only conserve water and reduce chemical usage but also enhance productivity and crop quality. AI continues to play a pivotal role in ensuring food security and sustainability in farming practices worldwide (Wao, Wao, & Pandey, 2023).

Artificial Intelligence (AI) enhances energy management by analyzing data to forecast demand patterns, thereby improving efficiency and minimizing waste. AI also supports the circular economy by extending the lifecycle of materials and energy through advanced analytics and predictive models. In urban settings, AI-driven smart grids and management systems enable real-time adjustments in energy distribution, facilitating the integration of renewable energy sources and reducing reliance on fossil fuels. AI's decision-support capabilities further promote energy-efficient building designs and urban planning strategies, while insights into consumer behavior encourage sustainable energy practices. Overall, AI plays a pivotal role in advancing energy decarbonization and sustainability efforts in the built environment (Awuzie, Ngowi, & Aghimien, 2024).

Future directions include a heightened focus on interpretable machine learning and explainable AI, particularly in the context of medical image assessment and cancer research. Additionally, efforts toward enhancing privacy and security frameworks in healthcare AI applications are expected to continue (Mishra, Ahmed, Shuja, Kumar, & Qtaishat, 2023)

Future opportunities for AI in education include streamlining administrative tasks, enhancing student learning experiences, and supporting research activities. By addressing challenges such as academic integrity concerns, user input understanding, and resource allocation, proactive measures can pave the way for the responsible and effective integration of AI technologies in higher education. This will enable institutions to create a more efficient, effective, inclusive, and innovative educational environment (Chukwuere, 2024).

8. CONCLUSION

AI holds immense potential for advancing the Sustainable Development Goals (SDGs) across various sectors including healthcare, education, urban planning, agriculture, energy, and environmental conservation. It can facilitate more accurate diagnosis and treatment in healthcare, personalized learning experiences in education, efficient urban infrastructure planning, precision agriculture techniques, renewable energy optimization, and biodiversity conservation efforts. However, challenges such as ethical considerations, data privacy concerns, accessibility issues, and the digital divide need to be addressed to ensure equitable and sustainable deployment of AI technologies for SDGs. Additionally, there's a need for interdisciplinary collaboration, capacity building, and policy frameworks to maximize the positive impact of AI while mitigating potential risks and disparities.

Continued investment in AI for sustainable development is crucial as it offers transformative solutions across sectors like healthcare, education, urban planning, agriculture, energy, and environmental conservation. These investments enable more efficient resource use, better decision-making, and improved problem-solving, advancing progress toward the SDGs. However, sustained investment is needed to address challenges like ethics, data privacy, and the digital gap, ensuring fair and responsible AI deployment. Prioritizing ongoing AI investment can unlock its full potential for a sustainable and prosperous future.

Our review highlights AI's crucial role in advancing SDGs across various sectors. By harnessing AI technologies in healthcare, education, urban planning, agriculture, energy, and environmental conservation, we can catalyze transformative change and address complex challenges facing our world today. However, to fully realize the potential of AI for sustainable development, concerted efforts are required. Collaboration, investment, and research are essential to overcome ethical, privacy, and digital gap challenges. Stakeholders must ensure responsible AI deployment for a sustainable, inclusive future.

CONFLICT OF INTERESTS

None

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REFERENCES

- Al Kuwaiti, A., Nazer, K., Al-Shehri, S., Al-Reedy, A., Al-Muhanna, A., Subbarayalu, A. V., . . . Al-Muhanna, F. A. (2023). [A Review of the Role of Artificial Intelligence in Healthcare.](#)
- Hamdan, A. M., Ibekwe, K., Ilojiana, V., Etukudoh, E. A., & Umoh, A. A. (2024, January). [AI and machine learning in climate change research: A review of predictive models and environmental impact.](#)
- Nishant, R., Kennedy, M., & Corbett, J. (2020, August). [Artificial intelligence for sustainability: Challenges, opportunities, and a research agenda.](#)
- Tezpal, M., Ghosh, S., Lalwani, R., Yadav, D., & Yadav, A. K. (2024). [Artificial Intelligence in Health Care – A Study on Perceptions of and Readiness for Artificial Intelligence in Health Care Professionals.](#)
- Awuzie, B. O., Ngowi, A., & Aghimien, D. O. (2024). [Towards built environment Decarbonisation: A review of the role of Artificial intelligence in improving energy and materials' circularity performance.](#)
- Burry, M. (2022). [A new agenda for AI-based urban design and planning.](#)
- Chukwuere, J. (2024, March). [The Future of AI Chatbots in Higher Education.](#)
- Collins, A. C. (2024, April). [Harnessing Innovations in AI and Robotics for Environmental Conservation: A Comprehensive Overview.](#)
- Collins, C., Dennehy, D., Conboy, K., & Mikalef, p. (2021). [Artificial intelligence in information systems research: A systematic literature review and research agenda.](#)
- Fan, Z., Yan, Z., & Wen, S. (2007). [Deep Learning and Artificial Intelligence in Sustainability: A Review of SDGs, Renewable Energy, and Environmental Health.](#)
- Göçen, A., & Aydemir, F. (2020). [Artificial Intelligence in Education and Schools.](#)
- Haklıdır, F. S. (2021). [Artificial Intelligence Applications in Renewable Energy.](#)

- Kleespies, M. W., & Dierkes, P. W. (2022). The importance of the Sustainable Development Goals to students of environmental and sustainability studies—a global survey in 41 countries.
- Lajara, B. M., Tudela, L. M., & Yadav, P. (2024). The Role of AI in Assessing and Achieving the Sustainable Development Goals (SDGs). In B. M. Lajara, L. A. Tudela, & P. Yadav.
- Mishra, A. C., Das, J., & Awtar, R. (2024, April). An Emerging Era Of Research In Agriculture Using AI.
- Mishra, H. M., Ahmed, B., Shuja, M., Kumar, M., & Qtaishat, A. (2023). Future Directions of Artificial Intelligence and Machine Learning in Healthcare: A Systematic Analysis and Mapping Study.
- Naeeni, S. K., & Nouhi2, N. (2023, Oct). The Environmental Impacts of AI and Digital Technologies.
- Nasir, O., Javed, R. T., Gupta, S., Vinuesa, R., & Qadir, J. (2023, February). Artificial intelligence and sustainable development goals nexus via four vantage points.
- Nishar, S. (2023). Artificial Intelligence in Automation and Robotics: Transforming Industries and Enhancing Efficiency.
- Parashar, A., Mabrouki, J., & Sharma, J. (2024, February). AI and Smart Technologies for Smart Agriculture Environment.
- Patil, A., & Mahind , R. (2017). A Review Paper on General Concepts of "Artificial Intelligence and Machine Learning ".
- Pradhan, P., Costa, L., Rybski, D., Lucht , W., & Kropp, J. P. (2017). A Systematic Study of Sustainable Development Goal (SDG) Interactions.
- Saini, N. (2023). RESEARCH PAPER ON ARTIFICIAL INTELLIGENCE & ITS APPLICATIONS.
- Soori, M., Arezoo, B., & Roza, D. (2023). Artificial intelligence, machine learning and deep learning in advanced robotics, a review.
- Vinuesa, R., Azizpour, H., Leite, L., Balaam, M., Dignum, V., Domisch, S., . . . Felländer, A. (2020). The role of artificial intelligence in achieving the Sustainable Development Goals.
- Wao, A. A., Wao, A. A., & Pandey, J. (2023, July). Artificial Intelligence in Agricultural Engineering.
- Yadav, P., Tudela, L. A., & Marco-Lajara, B. (2024, March). The Role of AI in Assessing and Achieving the Sustainable Development Goals (SDGs).