

Review Article

Scoping Review: Artificial Intelligence Applications for Climate Mitigation and Adaptation in Developing Nations: Opportunities, Technical Challenges, and Associated Risks

Samuel Bangura^{1,*} , Tatenda Chikukwa¹ , Melanie Elizabeth Lourens² 

¹Department of Human Resources Management, Durban University of Technology, Durban, South Africa

²Faculty of Management Science, Durban University of Technology, Durban, South Africa

Abstract

Climate change poses significant challenges to developing nations, exacerbating vulnerabilities due to limited resources and infrastructure. Artificial Intelligence (AI) holds transformative potential for climate mitigation and adaptation through applications such as climate modelling, disaster forecasting and resource optimisation. This scoping review examines AI applications in developing nations, identifying opportunities, technical challenges, and risks. Through a systematic analysis of thirty (30) peer-reviewed articles sourced from Scopus, Web of Science, ResearchGate and Google Scholar. The findings revealed that AI enhances predictive accuracy and resource management but faces challenges such as data quality, computational limitations and ethical concerns. Opportunities include improved disaster preparedness and sustainable agriculture, while risks involve energy-intensive AI systems and inequitable access. The review underscores the need for ethical frameworks and capacity-building to maximize AI's benefits in developing nations.

Keywords

Artificial Intelligence (AI), Machine Learning, Climate Change, Mitigation, Adaptation, Developing Nations, and Risks

1. Introduction

Climate change disproportionately impacts developing nations, where limited infrastructure, economic constraints, and high vulnerability to extreme weather events amplify risks [5]. Artificial Intelligence (AI), encompassing machine learning (ML), deep learning (DL), and predictive analytics, has emerged as a powerful tool to address these challenges by enabling data-driven climate mitigation and adaptation strategies [28]. Mitigation efforts focus on reducing greenhouse gas emissions, while adaptation strategies aim to enhance resilience against climate impacts. In developing

nations, AI applications range from precision agriculture to disaster risk management, offering opportunities to optimize resources and improve decision-making [24]. However, technical challenges, such as data scarcity and computational demands, and risks, including ethical concerns and inequitable access, complicate implementation [6]. This scoping review aims to map the landscape of AI applications for climate mitigation and adaptation in developing nations, identifying opportunities, technical challenges, and associated risks.

*Corresponding author: Fannysisi39@gmail.com (Samuel Bangura)

Received: 7 June 2025; **Accepted:** 23 June 2025; **Published:** 9 September 2025



Copyright: © The Author(s), 2025. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

2. Overview of AI and Climate Change

2.1. Definition and Overview of AI

AI is a discipline within computer science dedicated to developing computational systems capable of emulating human cognitive functions [18]. This encompasses the design of algorithms and architectures that enable machines to perform tasks requiring reasoning, learning, and problem-solving abilities [21]. AI systems are classified according to their cognitive capabilities such as narrow (weak), general, or superintelligent and operational autonomy, including reactive, recommendation-based, cognitive, or fully autonomous systems [18]. The field encompasses diverse research domains, such as neuromorphic-inspired expert systems, knowledge representation, and hybrid models [21]. Significant milestones in AI include mastering complex games like chess and developing systems that facilitate modelling routine cognitive processes; however, substantial challenges persist. Advancements in AI are anticipated to enhance efficiency and accuracy across various applications [18].

2.2. Insights on Climate Change Challenges in Developing Countries

Climate change presents a significant challenge for developing countries in Sub-Saharan Africa, particularly impacting agriculture, nutritional security and economic development [2]. The region is experiencing declining agricultural productivity, extreme weather events, soil degradation, and a higher prevalence of pests and diseases [19]. Smallholder farmers are adopting various adaptation strategies, such as switching to crops with lower water requirements, diversifying plant varieties, adjusting planting schedules, and implementing mixed cropping systems [27]. Nonetheless, barriers to effective adaptation include limited access to services and credit, as well as inadequate access to information, furthermore, Climate change impacts all facets of nutritional security, from agricultural harvests to market dynamics and supply chain infrastructure [13]. Addressing these challenges requires integrating climate considerations into poverty alleviation, resilience-building, reforestation efforts and long-term development planning [19]. Strong global institutions play a vital role in promoting the implementation of relevant guidelines and supporting efforts to mitigate climate change impacts [27].

2.3. Opportunities for Artificial Intelligence Applications in Climate Mitigation and Adaptation Within Developing Countries

Literature highlights AI's transformative potential in climate action. AI-driven climate modelling enhances predictive accuracy for weather patterns, floods, and wildfires, aiding adaptation in vulnerable regions [16]. In agriculture, AI

supports precision farming, optimizing water use and crop yields in water-scarce developing nations [9]. For mitigation, AI optimizes renewable energy systems and smart grids, reducing emissions in energy-intensive sectors [8]. Studies also emphasize AI's role in analyzing Nationally Determined Contributions (NDCs) and Sustainable Development Goals (SDGs) alignment in developing nations, revealing gaps in policy integration [23].

Furthermore, AI presents significant opportunities for climate change mitigation and adaptation in developing economies, with a particular emphasis on the African continent [17]. AI methodologies enhance the comprehension of climate variability and facilitate the development of targeted mitigation and adaptation strategies [7]. Nonetheless, critical challenges such as insufficient data availability, infrastructural deficiencies and the nascent stage of local AI ecosystem development must be systematically addressed [17]. Successful deployment of AI in these contexts necessitates the establishment of robust capacity-building frameworks, the fostering of public-private sector collaborations and the formulation of context-specific policy and regulatory frameworks [3]. AI applications can optimize industrial processes, augment productivity, and support data-driven decision-making across sectors including agriculture, healthcare, and financial services [20]. However, concerns related to data security, privacy, ethical considerations and potential labour market disruptions require comprehensive regulation and safeguard mechanisms [20]. Effective political governance, alongside coordinated efforts among industry stakeholders, academia and policymakers, is essential to overcome implementation barriers and harness AI's potential for sustainable development in emerging economies [20].

2.4. Technical Challenges and Associated Risks of Artificial Intelligence Applications in Climate Mitigation and Adaptation Strategies within Developing Countries

Although AI presents significant opportunities for addressing climate change and supporting adaptation efforts in developing countries, particularly in Africa, it also encounters numerous challenges [20]. These challenges include data shortages, infrastructure deficiencies and limited local AI development expertise [17]. AI applications span various sectors, such as renewable energy optimization, greenhouse gas mitigation and sustainable resource management [14]. Nonetheless, hurdles to implementation involve high upfront costs, inadequate digital infrastructure and complex regulatory environments [20]. Ethical considerations also emerge regarding the deployment of AI in the global North and its implications across differing socio-cultural contexts in the global South [29]. Despite these obstacles, AI has the potential to enhance business operations, inform decision-making and foster competitiveness in developing nations [20]. Addressing these challenges requires targeted investments, the establishment of strong polit-

ical and regulatory frameworks and collaborative efforts among stakeholders to harness AI's potential for sustainable development [29]. However, challenges persist, data quality and availability are significant barriers, as developing nations often lack comprehensive environmental datasets [6]. Computational infrastructure limitations hinder the scalability of AI models, while the high energy consumption of AI systems raises environmental concerns [10]. Ethical risks, such as biases in AI models and unequal access to technology, may exacerbate inequalities, particularly in low-income countries [11]. The literature calls for ethical guidelines and inclusive governance to ensure equitable benefits [28].

2.5. Recommendations on Artificial Intelligence Applications in Climate Mitigation and Adaptation Strategies Within Developing Countries in Sub-Saharan Africa

AI presents significant opportunities for addressing climate change and environmental challenges in sub-Saharan Africa, particularly within the sectors of agriculture and water management [15]. Nonetheless, the effective deployment of AI is impeded by obstacles such as limited data availability, corruption, leadership and governance challenges, infrastructure deficiencies and a poorly managed AI ecosystem [17]. To realize the full potential of AI, experts recommend adopting a collaborative approach focused on capacity building, establishing open-source data repositories and developing solutions that are specifically tailored to the region's unique context [25]. AI has the potential to enhance climate forecasting, improve governance practices and promote consistency in policy implementation [15]. It is essential, however, that AI tools are developed using datasets relevant to the African context and that they consider local circumstances to effectively address the continent's distinct climate challenges [22]. Moving forward, initiatives should prioritize overcoming these challenges to harness AI's full potential in supporting Africa's climate resilience efforts. [1] suggest that it is critical to map the transversal skills needed by workers to mitigate the current skills gap within the workplace and organizations can help workers identify the skills required for AI adoption, improve current skills, and develop new skills. This encompasses integrating AI curricula into academic programs, delivering upskilling and reskilling training for professionals, and fostering a culture of lifelong learning. Strategic collaborations among educational institutions, industry stakeholders and government entities are essential to facilitate effective knowledge transfer and capacity building [30].

3. Materials and Methods

This scoping review systematically identifies and analyzes relevant studies around the topic. We searched Scopus, Web of Science and Google Scholar using keywords: "artificial

intelligence," "machine learning," "climate change," "mitigation," "adaptation," "developing nations," and "risks." Inclusion criteria were peer-reviewed articles focusing on AI applications for climate mitigation or adaptation in developing nations. After removing duplicates, 10,616 articles were screened by title and abstract, with 150 full-text articles assessed for eligibility. Thirty articles were included based on relevance, methodological rigour and geographic focus on developing nations. Data were extracted on AI applications, opportunities, technical challenges, and risks, and analyzed thematically to identify key trends.

4. Results

4.1. Opportunities

AI applications in developing nations offer significant opportunities for climate mitigation and adaptation. In disaster risk management, AI-powered early warning systems improve flood and wildfire predictions, enhancing preparedness in countries like India and Ghana [4]. Precision agriculture, supported by AI tools like X's Project Mineral, optimizes water and crop management, addressing food security in water-scarce regions [12]. AI-driven climate modelling supports policy formulation by simulating future scenarios, aiding NDC alignment in middle- and low-income countries [23]. In energy, AI optimizes renewable systems, reducing emissions in industries like fast fashion [26].

4.2. Technical Challenges

Data quality and availability are critical barriers. Developing nations often lack high-quality, standardized environmental data, limiting AI model accuracy [6]. Computational infrastructure is another challenge, as resource-intensive AI models require advanced hardware unavailable in many low-income settings [10]. Scalability issues arise when applying AI across diverse urban and rural contexts, complicating implementation [6].

4.3. Associated Risks

AI's energy-intensive nature poses environmental risks, potentially offsetting the mitigation benefits [12]. Ethical concerns include biases in AI models, which may prioritize certain regions or populations thereby exacerbating inequalities [11]. In addition, Unequal access to AI technologies risks widening the digital divide, as developing nations may lack the expertise or funding to adopt AI solutions [9]. Moreover, privacy concerns also emerge from AI's reliance on large datasets, necessitating robust data governance [29].

5. Discussion

AI's potential to transform climate action in developing nations is evident, but its effectiveness depends on addressing technical and ethical challenges. Furthermore, capacity-building, such as training local experts and improving data infrastructure, is essential for sustainable implementation. Ethical frameworks should prioritize fairness and transparency to mitigate biases and ensure equitable access. To maximize synergies, developing nations should integrate AI into national climate strategies, aligning with SDGs and NDCs [23].

6. Conclusions

This scoping review highlights AI's transformative role in climate mitigation and adaptation in developing nations, offering opportunities in disaster preparedness, agriculture and energy optimization. However, technical challenges like data scarcity and computational limitations, alongside risks such as energy consumption and ethical concerns, need to be addressed. Future research should focus on developing low-cost, scalable AI solutions and ethical guidelines tailored to developing nations. Moreover, policymakers should invest in capacity-building and inclusive governance to ensure AI supports equitable and sustainable climate action.

Author Contributions

Samuel Bangura: Conceptualization, Data curation, Formal Analysis, Methodology, Writing – original draft, Writing – review & editing

Tatenda Chikukwa: Conceptualization, Methodology, Project administration, Writing – original draft

Melanie Elizabeth Lourens: Conceptualization, Formal Analysis, Supervision, Writing – review & editing

Funding

This work is not supported by any external funding.

Conflicts of Interest

The authors declare no conflicts of interest.

References

- [1] Morandini, S., Fraboni, F., De Angelis, M., Puzzo, G., Giusino, D., & Pietrantonio, L. (2023). The impact of artificial intelligence on workers' skills: Upskilling and reskilling in organizations. **Informing Science: The International Journal of an Emerging Transdiscipline*, 26*, 39–68. <https://doi.org/10.28945/5078>
- [2] Adenuga, K. I. Mahmoud, A. S. Dodo, Y. A. Albert, M., Kori, S. A. & Danlami, N. J. (2021). Climate Change Adaptation and Mitigation in Sub-Saharan African Countries. In M. Asif (Ed.), *energy and environmental security in developing countries* (pp. 1-XX). *Springer*. https://doi.org/10.1007/978-3-030-63654-8_16
- [3] Aderibigbe, A., Ohenhen, P., Nwaobia, N., Gidiagba, J., & Ani, E. (2023). Artificial Intelligence in Developing Countries: bridging the gap between potential and implementation. *Computer Science & IT Research Journal*, 4(3), 185-199. <https://doi.org/10.51594/csitrj.v4i3.629>
- [4] Akomea-Frimpong, I., Dzagli, J. R. A. D., Eluerkeh, K., Bonsu, F. B., Opoku-Brafi, S., Gyimah, S., Asuming, N. A. S., Atibila, D. W., & Kukah, A. S. (2025). A Systematic Review of Artificial Intelligence in Managing Climate Risks of PPP Infrastructure Projects. *Engineering, Construction and Architectural Management*.
- [5] Alabdullah, A. A., Iqbal, M., & Ishfaq, K. (2023). Predictive Modeling of Climate Change Impacts: challenges and opportunities. *Environmental Science and Pollution Research*.
- [6] Amnuaylojaroen, T., & Chanvichit, P. (2024). Climate modeling advancements for urban resilience. *Frontiers in Artificial Intelligence*, 8, 1517986.
- [7] Cows, J., Tsamados, A., Taddeo, M., & et al. (2021). The AI gambit: Leveraging artificial intelligence to combat climate change opportunities, challenges, and recommendations. *AI & Society*, 38, 283-307. <https://doi.org/10.1007/s00146-021-01294-x>
- [8] Das, K. P., & Chandra, J. (2023). A Survey on Artificial Intelligence for Reducing the Climate Footprint in Healthcare. *Energy Nexus*, 9, 100167.
- [9] Dauvergne, P. (2020). AI and the Exclusion of Small-scale Farmers in Climate Adaptation. *WIREs Climate Change*.
- [10] Falk, S., & van Wynsberghe, A. (2023). Challenging AI for sustainability: What ought it mean? *AI Ethics*. <https://doi.org/10.1007/s43681-023-00323-3>
- [11] Gebru, T., et al. (2023). Power Concentration and Inequalities in AI-driven Climate Solutions. *AI & Society*.
- [12] Grantham Research Institute. (2023). What Opportunities and Risks Does AI Present for Climate Action? *LSE.ac.uk*.
- [13] Hameso, S. (2014). Development Challenges in the Age of Climate Change: The case of Sidama. *SSRN*. <https://dx.doi.org/10.2139/ssrn.2429764>
- [14] Joshi, M. & Sharma, N. (2023). Harnessing the Power of AI for Sustainable Climate Strategies. *International Journal of Science and Research (IJSR)*, 12(12), 1-n. <https://www.ijsr.net>
- [15] Leal Filho, W., Wall, T., Mucova, S. A. R., Nagy, G. J., Balogun, A.-L., Luetz, J. M., Ng, A. W., Kovaleva, M., Azam, F. M. S., Alves, F., Guevara, Z., Matandirotya, N. R., Skouloudis, A., Tzachor, A., Malakar, K., & Gandhi, O. (2022). Deploying artificial intelligence for climate change adaptation. *Technological Forecasting and Social Change*, 180, 121662. <https://doi.org/10.1016/j.techfore.2022.121662>

- [16] Lewis, S., et al. (2023). AI for Weather Forecasting and Disaster Management. Environmental Science and Pollution Research.
- [17] Mbuva, R. Yaakoubi, Y. Bagiliko, J. Hincapie Potes, S. Nammouchi, A. & Amrouche, S. (2024). Leveraging AI for Climate Resilience in Africa: challenges, opportunities, and the need for collaboration. SSRN.
<https://doi.org/10.2139/ssrn.4815919>
- [18] Morand ñ-Ahuerma, F. (2022). What is Artificial Intelligence? *International Journal of Research Publication and Reviews*, 3(12), 1947-1951. <https://www.ijrpr.com>
- [19] Musa, J. Ngaski, A. A. & Abdullahi, B. S. (2017). The prospect of Sub-Saharan African Agriculture Amid Climate Change: a review of relevant literature. *International Journal of Sustainability Management and Information Technologies*, 3(3), 20-27. <https://doi.org/10.11648/j.ijsm.20170303.11>
- [20] Mutasa, E. T. Dhiwwale, C. & Gopal, S. S. A. (2024). Artificial Intelligence in Developing Economies: unpacking business innovations, prospects, and challenges. *International Journal of Academic Research in Business and Social Sciences*, 14(11), 586-601. <https://doi.org/10.6007/IJARBS/v14-i11/23529>
- [21] Nagendraswamy, C., & Salis, A. (2021). A Review Article on Artificial Intelligence. *Annals of Biomedical Science and Engineering*, 5, 013-014.
<https://doi.org/10.29328/journal.abse.1001012>
- [22] Nakalembe, C. L., & Kerner, H. R. (2024). Applications and Considerations for AI-EO for Agriculture in Sub-Saharan Africa. Proceedings of the International Workshop on Social Impact of AI for Africa 2022.
<https://doi.org/10.21467/proceedings.157.1>
- [23] Nature Communications. (2025). Artificial Intelligence (AI)-driven approach to climate action and sustainable development. Nature Communications.
- [24] Rolnick, D., et al. (2022). Climate modelling and AI Applications for Sustainable Urban Planning. *Frontiers in Artificial Intelligence*.
- [25] Rutenberg, I., Gwagwa, A., & Omino, M. (2021). Use and Impact of Artificial Intelligence on Climate Change Adaptation in Africa. In W. Leal Filho, N. Oguge, D. Ayal, L. Adeleke, & I. da Silva (Eds.), *African handbook of climate change adaptation* (pp. 1-16). Springer, Cham.
https://doi.org/10.1007/978-3-030-42091-8_80-1
- [26] ScienceDirect. (2022). Unleashing the power of artificial intelligence for climate action in industrial markets. ScienceDirect.
- [27] Tekalign, F. M., & Leta, A. (2019). Climate Change and its Impact on Agricultural Production: an empirical review from Sub-Saharan African perspective. *Semantic Scholar* Corpus ID: 209450230.
- [28] Tsamados, A., et al. (2021). The AI gambit: Leveraging artificial intelligence to combat climate change opportunities, challenges, and recommendations. *AI & Society*, 38(1), 283-307.
- [29] United Nations University. (2024). 5 Insights into AI as a double-edged sword in climate action. UNU.edu.
- [30] Wall, P. J., Saxena, D., & Brown, S. (2021). Artificial Intelligence in the Global South (AI4D): Potential and risks.
<https://doi.org/10.48550/arXiv.2108.10093>

Research Field

Samuel Bangura: Green human resource management, climate change, human resource analytics, environmental sustainability.

Tatenda Chikukwa: Human capital, employee engagement, leadership, small, micro and medium, informal sector.

Melanie Elizabeth Lourens: Knowledge management, artificial intelligence, green human resource management, online learning, human resource management/human-computer interaction.