

Positioning Africa for Sustainable AI: Building the Governance, Innovation Systems, and Resource Capabilities for Climate-Resilient Growth

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Abstract

Artificial intelligence is increasingly positioned as a critical enabler of climate action and sustainable development, offering new tools to address complex, interconnected challenges spanning environmental, economic, and social systems. For Africa—one of the world’s most climate-vulnerable regions—the potential benefits of AI are significant, yet uneven global AI trajectories risk reinforcing dependency, data asymmetries, and unequal value capture if left unexamined. This paper advances the argument that Africa’s strategic opportunity lies not in the passive adoption of externally designed AI systems but in shaping governance-led, context-aware, and sustainability-oriented AI pathways. It examines AI’s role in climate mitigation, adaptation, and decision-making, alongside the structural constraints facing African adoption, including infrastructure gaps, skills shortages, and data inequities. At the same time, it highlights Africa’s distinctive comparative advantages—rooted in indigenous knowledge systems, demographic diversity, and human-centred values—as a foundation for global leadership in responsible and sustainable AI. The paper concludes by outlining actionable pathways through which Africa can help redefine AI governance in the service of climate resilience, social equity, and the global public good.

Definitions of Key and Relevant AI Terms and Concepts

Artificial Intelligence (AI)

Artificial intelligence refers to computational systems designed to perform tasks that typically require human intelligence. These tasks include perception, pattern recognition, learning, reasoning, decision-making, and language understanding. In sustainability contexts, AI is primarily valued for its ability to analyse complex systems, process large volumes of heterogeneous data, and support predictive and optimisation-based decision-making.

Machine Learning (ML)

Machine learning is a subset of AI that enables systems to learn patterns from data and improve performance over time without being explicitly programmed for each task. ML techniques underpin most contemporary AI applications used in climate modelling, energy optimisation, agriculture, and environmental monitoring.

Deep Learning

Deep learning is a subset of machine learning that uses multi-layered artificial neural networks to model complex, non-linear relationships in data. It is particularly effective for image recognition, speech processing, natural language understanding, and remote sensing applications relevant to environmental sustainability.

Generative Artificial Intelligence (Generative AI)

Generative AI refers to AI systems capable of creating new content—such as text, images, code, audio, or simulations—based on patterns learned from existing data. Examples include large language models and image-generation systems. In sustainability contexts, generative AI is increasingly used for scenario analysis,

materials discovery, climate modelling augmentation, and decision-support, but it also raises concerns regarding energy use, data provenance, and misinformation.

Large Language Models (LLMs)

Large language models are a class of generative AI systems trained on vast corpora of text data to understand and generate human-like language. They rely on deep neural network architectures and are capable of tasks such as summarisation, translation, reasoning, and content generation. While LLMs enhance accessibility to knowledge and decision-support, they are computationally intensive and pose challenges related to bias, transparency, and environmental footprint.

Fuzzy Logic

Fuzzy logic is an AI and control-system approach that allows reasoning with degrees of truth rather than binary true/false values. It is particularly useful for modelling uncertainty, ambiguity, and imprecise information—common characteristics of environmental and socio-ecological systems. Fuzzy logic has long been applied in climate control systems, water management, and decision-support tools.

Prediction Algorithms / Prediction Machines

Prediction algorithms are AI systems designed to forecast future outcomes based on historical data. In sustainability applications, they are used to predict weather patterns, energy demand, crop yields, disaster risks, and emissions trajectories. Their effectiveness depends heavily on data quality and representativeness.

Clustering Algorithms

Clustering algorithms group data points based on similarity across selected variables. In environmental and sustainability contexts, clustering is used for ecosystem

classification, climate-zone analysis, land-use planning, and socio-economic segmentation.

Synthetic Data

Synthetic data is artificially generated data that mimics the statistical properties of real-world data. It is often used to address data scarcity, privacy constraints, or under-representation in training datasets. While useful, synthetic data must be carefully governed to avoid reinforcing biases or generating misleading outputs.

AI Governance

AI governance refers to the frameworks, policies, standards, and institutional arrangements that guide the design, development, deployment, and oversight of AI systems. Effective AI governance seeks to maximise societal and environmental benefits while minimising risks related to ethics, safety, equity, environmental impact, and accountability.

Responsible AI

Responsible AI denotes the practice of developing and deploying AI systems in ways that are ethical, transparent, inclusive, accountable, and aligned with societal and environmental objectives. It integrates technical safeguards with governance, human oversight, and context-specific risk management.

Green AI

Green AI refers to the design and use of AI systems that minimise environmental impact, particularly energy consumption, carbon emissions, water use, and electronic waste. It emphasises efficiency, lifecycle assessment, and alignment with renewable energy and circular-economy principles.

1. Introduction: AI, Sustainability, and Africa's Development Imperative

The world is confronting a convergence of systemic crises: accelerating climate change, biodiversity loss, water scarcity, food insecurity, and widening socio-economic inequality. Despite decades of global commitments—from the Rio Conventions to the Paris Agreement and the Sustainable Development Goals (SDGs)—progress remains uneven, with fewer than one-fifth of SDG targets currently on track. These challenges are deeply interconnected, non-linear, and characterised by uncertainty, feedback loops, and long-term horizons that strain traditional policy and planning tools.

Artificial intelligence has emerged as a general-purpose technology with the potential to transform how societies understand, model, and manage such complex systems. Advances in machine learning, remote sensing, optimisation, and generative modelling offer new capabilities to process vast, heterogeneous datasets, identify patterns invisible to human analysis, and support faster, more informed decision-making.

AI's rapid diffusion across sectors—from energy systems and agriculture to finance, public administration, and climate science—has positioned it as a central tool in addressing sustainability challenges. Globally, AI is increasingly deployed to optimise energy use, enhance climate modelling, strengthen early-warning systems, support precision agriculture, and inform policy decisions in contexts characterised by uncertainty and risk. As a result, AI is now widely framed as a critical enabler of climate action and sustainable development.

For Africa, the stakes are particularly high. The continent is among the most climate-vulnerable regions globally, despite having contributed least to historical greenhouse-gas emissions. At the same time, Africa faces pressing development priorities: poverty reduction, job creation, industrialisation, infrastructure expansion, and improved service delivery. AI appears to offer a means of pursuing these objectives more efficiently and resiliently. Yet Africa largely remains a net importer of AI technologies, data infrastructures, and governance frameworks developed elsewhere—raising concerns

about dependency, data sovereignty, unequal value capture, and the reinforcement of existing global asymmetries.

The AI moment therefore presents Africa with a profound strategic choice. On the one hand, AI offers the possibility of leapfrogging legacy systems and accelerating progress towards climate resilience and inclusive development. On the other, if current trajectories remain unchallenged, AI risks entrenching new forms of dependency, extractive data practices, and asymmetric power relations. The central question is not whether AI will shape Africa's sustainable development pathway, but whether Africa will meaningfully shape the terms on which AI is designed, governed, and deployed.

2. AI as a Transformative Enabler of Environmental Sustainability

There is a growing consensus that AI can play a catalytic role in advancing the SDGs, particularly in relation to climate action, food security, water management, and resilient infrastructure. Recent studies highlight AI's capacity to process vast and heterogeneous datasets, uncover non-linear relationships, and support scenario modelling in complex systems. In the climate domain, AI-enabled tools are already improving emissions monitoring, enhancing climate-risk forecasting, optimising renewable energy integration, and supporting disaster preparedness.

Crucially, AI's sustainability potential lies not only in individual applications, but in its systemic character. When deployed coherently, AI can generate positive spillovers across multiple SDGs, linking climate action with economic productivity, social inclusion, and institutional effectiveness. This systems-level potential is particularly relevant for Africa, where development challenges are deeply interconnected and where climate impacts often exacerbate existing socio-economic vulnerabilities.

2.1 Climate Mitigation and Low-Carbon Transitions

AI has demonstrated significant potential to accelerate climate mitigation across energy, industry, transport, and urban systems. In the energy sector, machine-learning algorithms are increasingly used to forecast demand, optimise grid operations, and

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integrate variable renewable energy sources such as wind and solar. These capabilities are especially relevant for African power systems, which are often characterised by capacity constraints, high losses, and growing shares of distributed generation.

In industry and materials sectors, AI-driven modelling accelerates the discovery of low-carbon alternatives to emissions-intensive products such as cement, steel, and plastics. Generative models can simulate millions of molecular combinations, dramatically reducing the time and cost required to identify viable substitutes. In transport and logistics, AI-enabled route optimisation and fleet management reduce fuel consumption and emissions while improving efficiency.

AI also strengthens emissions measurement, reporting, and verification (MRV), a critical enabler of climate policy, carbon markets, and climate finance. Automated analysis of satellite imagery and sensor data improves transparency and reduces transaction costs—an important consideration for African countries seeking access to international climate finance and results-based mechanisms.

2.2 Climate Adaptation, Resilience, and Risk Management

Beyond mitigation, AI plays a critical role in climate adaptation and resilience—areas of existential importance for Africa. Predictive analytics and pattern recognition enhance early-warning systems for floods, droughts, cyclones, and heatwaves by integrating climate models with real-time meteorological and geospatial data. When coupled with effective governance and response mechanisms, such systems can save lives, protect infrastructure, and reduce economic losses.

In agriculture, AI supports precision farming through soil-moisture monitoring, yield forecasting, pest and disease detection, and climate-smart crop selection. These applications are particularly valuable in smallholder-dominated systems, where productivity gains translate directly into food security and livelihoods. In water management, AI optimises allocation, detects leakages, and supports basin-level planning under conditions of increasing variability.

Health systems also benefit from AI-enabled surveillance and modelling, improving preparedness for climate-sensitive diseases and health emergencies. Taken together, these applications illustrate how AI can enhance adaptive capacity across critical sectors.

2.3 Strengthening Sustainability Decision-Making

Perhaps most fundamentally, AI augments the analytical foundations of sustainability governance. By processing complex datasets spanning environmental, economic, and social dimensions, AI improves scenario analysis, systems modelling, and policy evaluation. This capability is essential for navigating the trade-offs inherent in sustainable development—between growth and conservation, short-term needs and long-term resilience.

3. AI Adoption: A Tall Order for Africa—Structural Constraints and Global Asymmetries

3.1 The Pace of Technological Change and Governance Lag

AI technologies are evolving at a pace that consistently outstrips regulatory, educational, and institutional adaptation. Advances in generative and increasingly autonomous systems have lowered barriers to deployment while amplifying potential risks. Policymakers and regulators—particularly in resource-constrained settings—struggle to keep pace, creating gaps in oversight and accountability.

This governance lag heightens the risk that AI systems are deployed without adequate consideration of environmental impacts, social externalities, or long-term sustainability objectives. It also increases reliance on external technology providers whose incentives may not align with local development priorities.

3.2 Infrastructure, Skills, and Capital Constraints

Advanced AI development and deployment require reliable electricity, high-performance computing, robust connectivity, and specialised human capital. Many African countries face deficits across all these dimensions. Energy systems remain constrained and carbon-intensive; digital infrastructure is unevenly distributed; and skills shortages persist across data science, engineering, and interdisciplinary sustainability fields.

Addressing these gaps requires substantial and sustained investment—often beyond the capacity of public budgets alone. While public–private partnerships and development finance are essential, they must be structured carefully to avoid reinforcing dependency or external control over strategic digital infrastructure.

3.3 Data Inequities and Sovereignty

Data is the lifeblood of AI systems, yet global data flows remain deeply unequal. Data poverty in many African contexts leads to under-representation in training datasets, resulting in biased or inaccurate models. At the same time, restrictive data governance regimes and fragmented cross-border rules limit access to climate and environmental data that constitute global public goods.

Balancing data sovereignty with the need for collaboration is therefore a central governance challenge. Without deliberate intervention, existing asymmetries risk being entrenched, with Africa supplying raw data or resources while value is captured elsewhere.

4. African Comparative Advantages and Strategic Opportunity

While much of the discourse focuses on Africa’s deficits, this perspective is incomplete. African scholarship on AI governance and development highlights distinctive strengths that represent a strategic opportunity for the continent and can enrich global approaches to sustainable AI.

4.1 Indigenous Knowledge Systems and Contextual Intelligence

African indigenous knowledge systems embody deep, place-based understandings of ecosystems, climate variability, and resilience strategies developed over centuries. When respectfully integrated into AI systems—through participatory data practices and co-design—such knowledge can enhance model relevance, robustness, and legitimacy. This integration challenges dominant paradigms that privilege purely technical or externally generated data.

4.2 Diversity, Demographics, and Innovation Potential

Africa's demographic diversity and youthful population represent a significant asset for inclusive innovation. Diversity in data, perspectives, and lived experience enhances creativity and reduces the risk of monocultural bias embedded in AI systems developed in more homogeneous contexts. Realising this potential requires investment in education, skills development, and inclusive innovation ecosystems.

4.3 Human-Centred Values and Ethical Orientation

Human-centred value systems—often articulated through concepts such as Ubuntu—emphasise relationality, solidarity, and collective well-being. These values offer an ethical lens for AI governance that foregrounds social and environmental outcomes over narrow efficiency or profit maximisation. Embedding such principles into AI design and governance can help align technological progress with broader societal goals.

4.4 Reframing Africa's Role in the Global AI Ecosystem

Africa's strategic opportunity lies in reframing its role within the global AI ecosystem. Rather than competing on scale in data-intensive and capital-heavy AI development, African actors can lead in governance innovation, context-aware applications, and sustainability-focused use cases. Climate adaptation, biodiversity conservation, water management, and inclusive energy transitions are domains where African leadership can be both locally transformative and globally relevant.

5. The Environmental Footprint of AI: Risks and Trade-Offs

The sustainability narrative around AI is incomplete without acknowledging the technology's own environmental footprint.

5.1 Energy Use and Greenhouse-Gas Emissions

Training and operating large AI models is energy-intensive, with data centres consuming substantial electricity and often relying on fossil-fuel-based grids. Without deliberate alignment with renewable energy and efficiency measures, AI deployment risks increasing emissions at a time when rapid reductions are required.

5.2 Materials, Mining, and Ecological Impacts

AI hardware depends on critical minerals such as lithium, cobalt, and rare earth elements. Their extraction and processing are associated with land degradation, water pollution, biodiversity loss, and social conflict. Given Africa's role as a major source of many such minerals, the environmental and social stakes are particularly high.

5.3 Water Use, Waste, and Circularity

Semiconductor manufacturing and data-centre cooling require substantial water resources, often in water-stressed regions. In addition, electronic-waste streams are growing rapidly, challenging waste-management systems and undermining circular-economy objectives. If unmanaged, these impacts risk undermining the very sustainability goals AI is meant to advance.

6. Risk Mitigation and Responsible Pathways

Reconciling AI deployment with sustainability objectives requires proactive risk mitigation strategies, including:

- **Green AI and energy alignment**, prioritising energy-efficient models and renewable-powered data centres.

- **Circular technology design**, embedding circular-economy principles into hardware lifecycles.
- **Responsible mining and materials governance**, ensuring environmental safeguards and community benefit-sharing.
- **Data governance for the public good**, enabling responsible cross-border data sharing while protecting rights and sovereignty.
- **Context-specific responsible AI frameworks**, integrating environmental, social, and ethical risk management tailored to African realities.

7. Actionable Recommendations

For governments

- Integrate AI explicitly into national climate, biodiversity, and sustainable-development strategies.
- Invest in renewable-powered digital infrastructure and regional computing hubs.
- Advance interoperable, Africa-led AI governance frameworks reflecting local priorities and values.

For industry and investors

- Align AI investments with sustainability metrics, disclosures, and long-term environmental objectives.
- Adopt responsible-AI-by-design approaches and transparent reporting on environmental impacts.
- Partner with local institutions to build skills, data capacity, and inclusive innovation ecosystems.

For academia and civil society

- Co-produce knowledge integrating AI, sustainability science, and indigenous perspectives.

- Build interdisciplinary capacity and AI literacy across society to enable informed participation and oversight.

8. Conclusion: Centering Africa in the Future of Sustainable AI

AI holds immense promise to help address the sustainability challenges confronting Africa and the world. Yet this promise will not be realised through technological adoption alone. It requires deliberate governance, ethical orientation, and investment choices that ensure AI advances—rather than undermines—climate, biodiversity, and social objectives.

Africa's opportunity lies not only in applying AI to local problems, but in shaping global conversations about what responsible, sustainable AI should look like. By leveraging indigenous knowledge, diversity, and human-centred values, Africa can offer a distinctive and necessary perspective—one that helps ensure humanity and the planet, rather than technological prowess alone, are the ultimate beneficiaries of AI-driven progress.

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