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AI Climate Sensors in Africa

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| This case study is part of the **African <AI & Equality> Toolbox**, which builds upon the methodology of the global <AI & Equality> Human Rights Toolbox—an initiative of Women At The Table in collaboration with the United Nations Office of the High Commissioner for Human Rights (OHCHR). The African Toolbox is a collaboration between the <AI & Equality> initiative and the African Centre for Technology Studies (ACTS). To learn more visit **aiequalitytoolbox.com**

Introduction

In a bustling Nairobi neighborhood near an industrial zone, residents had long suspected that the persistent coughs plaguing their children and the acrid smell hanging in the air were connected to the nearby factories. But without data, their concerns were dismissed by authorities as mere complaints. Meanwhile, in rural Tanzania, fishing communities noticed changes in weather patterns that affected their livelihoods, but lacked the evidence to understand or adapt to these shifts. These stories reflect a broader challenge across Africa: environmental injustices compounded by a lack of reliable data to document, understand, and address climate and pollution impacts.

Code for Africa's *sensors.AFRICA* initiative emerged from this gap between lived experience and documented evidence. What began as a response to journalists' struggles to report on air quality issues has evolved into a comprehensive AI-driven platform that empowers communities across the continent to monitor, understand, and advocate for their environmental rights.

The Genesis: From Data Scarcity to Community Empowerment

The *sensors.AFRICA* story began in newsrooms across Africa, where journalists faced a frustrating reality: they could see and smell the pollution, hear community complaints about deteriorating air quality, but had no reliable data to support their reporting. Traditional monitoring infrastructure, where it existed at all, was prohibitively expensive and often controlled by the same institutions that communities were trying to hold accountable.

Alicia Olago, an environmental scientist and the senior product manager of *sensors.AFRICA*, recalls the moment this challenge crystallized into action: "We realized that the absence of data wasn't just a technical problem—it was a justice issue. Communities were suffering, but without evidence, their voices were marginalized."

This recognition led to a fundamental principle that would guide the entire initiative: environmental data should be open, accessible, and controlled by the communities most affected by environmental challenges. But achieving this vision required more than just deploying sensors—it demanded a complete reimagining of how environmental monitoring could work in African contexts.

Building trust through technology: the community-centered approach

Unlike traditional top-down environmental monitoring systems, *sensors.AFRICA* adopted a community-centered approach from its inception. This wasn't merely a matter of good practice—it was essential for the initiative's success and sustainability.

In urban areas like Nairobi's Korogocho informal settlement, the team learned that simply installing sensors wouldn't work without deep community engagement. The process begins with what they call "entry through champions"—identifying community leaders, NGOs, or passionate residents who serve as bridges between the technical team and the broader community.

But champions alone aren't enough. The real breakthrough came through participatory mapping sessions, where community members gather around printed maps of their neighborhoods—created using open-source OpenStreetMap data—to identify pollution sources, vulnerable areas, and priority concerns. These sessions reveal nuanced perspectives that outside experts would never capture: women highlighting different pollution sources than men, elderly residents pointing to health impacts, youth identifying environmental changes over time.

"The map becomes a conversation starter," explains Olago. "When you see a grandmother pointing to a specific corner and explaining how the air changes when the wind shifts, you understand that data collection isn't just about technology—it's about dignity and agency."

Technical innovation driven by community needs

The technical architecture of *sensors.AFRICA* reflects the realities of African environments and communities. The sensors measure particulate matter (PM1, PM2.5, PM10), relative humidity, temperature, and GPS coordinates, transmitting data in real-time through IoT systems. But the real innovation lies in how these technical capabilities were adapted to address infrastructure challenges and community needs.

Power supply emerged as a critical challenge early in the project's development. In urban areas, frequent power fluctuations and load-shedding made grid-dependent sensors unreliable. In rural areas, many communities had no grid access at all. The solution came through solar-powered sensors with locally sourced panels and battery packs—a technical adaptation that also supported local economies and simplified maintenance.

Connectivity presented another challenge. While urban areas had multiple connection options, rural deployments often faced limited cellular coverage. The team developed IoT SIM cards that could bounce between networks, finding the strongest available signal. Memory cards provided backup storage to prevent data loss during connectivity interruptions. These weren't just technical fixes—they were solutions designed with community

sustainability in mind. Local sourcing meant that broken components could be replaced quickly without waiting for international shipments. Simple, robust designs meant that community members could perform basic maintenance themselves.

AI as a tool for environmental justice

The integration of artificial intelligence into *sensors.AFRICA* represents a natural evolution of the community-centered approach rather than a technological add-on. AI serves three primary functions within the initiative: filling data gaps, predicting environmental events, and making complex data accessible to diverse audiences.

Machine learning algorithms help predict and fill data gaps caused by sensor malfunctions, tampering, or connectivity issues. This isn't just a technical convenience—it ensures that communities don't lose critical evidence during important periods, such as when documenting pollution events for legal proceedings.

The AI-driven early warning system developed for Nakuru, Kenya, exemplifies how artificial intelligence can serve environmental justice. By analyzing real time sensor data, satellite data, alongside human sensor network data, the system predicts pollution events and sends alerts to residents through the AngaWATCH citizen App.. This gives communities advance warning to take protective measures, particularly important for vulnerable populations like children, pregnant women and the elderly.

Perhaps most importantly, AI helps make environmental data accessible across different literacy levels and languages. The system generates simplified visual displays using air quality indices, and creates monthly reports in local languages. This democratization of information transforms data from an elite resource into a community tool.

The power of open data and evidence-based advocacy

The true impact of *sensors.AFRICA* becomes clear through the stories of communities who have used the data for advocacy and change. In the Syokimau area outside Nairobi, residents suspected that a nearby factory was causing health problems in their community. Persistent chest problems among children, frequent pneumonia cases, and respiratory issues seemed connected to visible emissions from the industrial facility.

Working with *sensors.AFRICA*, the community installed air quality sensors that documented particulate matter levels well above WHO guidelines. The data provided the evidence base residents needed to approach authorities and media outlets. A 32-minute feature on Citizen TV, one of Kenya's most influential media houses, brought national attention to their situation, directly correlating the sensor data with community health impacts.

The story doesn't end with media coverage. Armed with documented evidence, residents took their case to the Kenyan National Environmental Tribunal. The combination of sensor data and community testimony created a compelling case that authorities couldn't dismiss as subjective complaints. This legal pathway, supported by concrete data, demonstrates how environmental monitoring can strengthen democratic institutions and environmental governance.

Similar stories have emerged across the continent. In Mukuru, another Nairobi informal settlement, sensor data documenting dangerous air quality levels was featured in The Star newspaper coverage titled "Mukuru fumes put 60 asthma patients a month in hospital." The direct correlation between environmental data and health outcomes provided the evidence base for policy discussions and intervention planning.

Expanding Horizons: The Earth Observation Vision

The success of air quality monitoring has inspired *sensors.AFRICA* to expand into comprehensive environmental monitoring through what they call "Earth Observation"—a vision that integrates ground sensors, drone imagery, and satellite data through AI analysis. This multi-modal approach addresses the full spectrum of environmental challenges facing African communities.

In partnership with *africanDRONE*, another Code for Africa initiative, the project plans to combine ground-based sensor data with aerial imagery to monitor deforestation, wildfires, floods, and drought impacts. AI algorithms analyze these diverse data streams to identify patterns, predict environmental events, and generate early warnings for communities.

Prior expansion into marine environments produced initiatives like tracking dynamite fishing through underwater acoustic sensors and the StormWatch project in Tanzania, which uses satellite remote sensing and climate models to protect fishermen from extreme weather events. Each expansion maintains the core principle of community ownership and open data access.

Navigating Challenges: Power, Politics, and Participation

The *sensors.AFRICA* initiative hasn't been without challenges. Ensuring sensor host safety, particularly when documenting pollution from powerful industrial actors, requires careful attention to data protection and anonymization. Regular check-ins with community hosts, secure data transmission, and strategic communication help protect participants while maintaining data integrity.

Political challenges emerge when sensor data conflicts with official narratives or powerful interests. The initiative addresses this through transparency, open data policies, and broad stakeholder engagement that includes government partners, civil society organizations, and

academic institutions. By making data publicly accessible through multiple channels —API endpoints for technical users, visual displays for general audiences, and detailed reports for researchers— the initiative builds broad-based support that's difficult for any single actor to suppress.

Sustainability represents an ongoing challenge, particularly in remote rural areas. The community-centered approach provides partial solutions through local capacity building, peer learning networks, and integration with existing community structures. Training local individuals to interpret data and communicate findings creates sustainable support systems that don't depend on continuous external intervention.

Rural adaptations: environmental monitoring in remote communities

Rural deployments of *sensors.AFRICA* require different approaches than urban installations. Rather than solely responding to journalist requests or citizen complaints, rural projects typically begin with requests from partner organizations that have established trust within communities. This reflects different power dynamics and the need for more careful navigation of community relationships.

Participatory mapping becomes even more crucial in rural settings, where environmental issues affect different community groups in distinct ways. Women might highlight water scarcity and indoor air pollution from cooking fires, while youth focus on land degradation affecting future livelihoods. Men might emphasize different pollution sources or economic impacts. These diverse perspectives ensure that monitoring systems capture the full range of community concerns.

Technical adaptations for rural environments go beyond power and connectivity solutions. Early warning systems must work through SMS rather than smartphone apps, to accommodate rural communities who often lack smartphones and have limited literacy levels. Training programs must account for different education levels and technological familiarity, often using visual aids and hands-on demonstrations rather than written materials.

The Earth Observation vision holds particular promise for rural communities facing complex environmental challenges. By integrating ground sensors with drone and satellite imagery, AI can monitor large geographical areas for deforestation, predict flood risks, and track drought impacts. This comprehensive monitoring supports both immediate community needs and broader policy discussions about rural development and climate adaptation.

Impact Beyond Numbers: Transforming Environmental Governance

The success of *sensors.AFRICA* can't be measured only in sensors deployed or data points collected. The initiative has fundamentally changed how environmental issues are discussed and addressed across participating communities. By providing communities with their own data, the project has shifted power dynamics in environmental governance.

Academic researchers now regularly use *sensors.AFRICA* data in their studies, including deep learning approaches that combine the community-generated data with other environmental datasets. This academic engagement validates the scientific quality of the data while ensuring that community concerns reach scholarly and policy audiences.

The integration of qualitative research—focus group discussions, key informant interviews, and participatory observations—alongside quantitative sensor data provides rich narratives that pure technical monitoring couldn't capture. This mixed-methods approach helps policymakers and researchers understand not just what environmental changes are occurring, but how they affect different community members and what solutions might be most appropriate.

Lessons for AI and Human Rights

The *sensors.AFRICA* case study offers several crucial insights for AI development that respects and promotes human rights:

— **Community ownership is essential:** The most sophisticated AI system fails if communities don't trust it, understand it, or control its use. Starting with community needs rather than technical capabilities ensures that AI serves justice rather than merely demonstrating technological prowess.

— **Participation must be genuine:** Tokenistic consultation differs fundamentally from the deep engagement required for effective AI systems. Participatory mapping, community-led site selection, and local capacity building create genuine ownership that sustains initiatives over time.

— **Technical design reflects values:** Every technical choice—from power systems to data transmission protocols—embodies assumptions about users, contexts, and priorities. Designing for African contexts required fundamental rethinking of standard approaches, resulting in more robust and sustainable systems.

- **Data justice requires open access:** Environmental data becomes a tool for justice only when communities can access, understand, and use it. Open data policies, multiple access channels, and diverse presentation formats ensure that information serves empowerment rather than extraction.

- **AI can democratize expertise:** Rather than replacing human judgment, AI in *sensors.AFRICA* amplifies community knowledge and makes technical information accessible to diverse audiences. This democratization of expertise strengthens rather than undermines human agency.

Looking forward: Scaling environmental justice

As *sensors.AFRICA* expands across the continent, each new deployment offers opportunities to refine the community-centered approach while adapting to different environmental, political, and social contexts. The initiative's success has inspired similar projects globally, demonstrating that the principles developed in African contexts have broader applicability.

The Earth Observation vision represents the next phase of development, where AI integration becomes more sophisticated while maintaining the core commitment to community ownership and environmental justice. By combining multiple data sources through AI analysis, the initiative can address increasingly complex environmental challenges while preserving the local knowledge and community agency that make it effective.

Perhaps most importantly, *sensors.AFRICA* demonstrates that AI can serve environmental justice when developed with rather than for affected communities. The initiative's success stems not from technological sophistication alone, but from recognizing that environmental data is ultimately about human dignity, community empowerment, and the right to a healthy environment.

The children in Nairobi who no longer suffer from unexplained respiratory illness, the fishing communities in Tanzania who receive advance warning of dangerous weather, and the residents across Africa who now have evidence to support their environmental concerns represent the true measure of AI's potential to serve human rights and environmental justice.

Resources:
sensors.AFRICA website | **StormWatch Platform** | **Seasensors Platform**

Mapping the AI Lifecycle HRIA Framework for sensors.AFRICA

1 **Stage 1: Objective and Team Composition**

The initiative began with clearly defined objectives rooted in community needs: providing reliable, open-access environmental data to support journalists, citizens, and policymakers in addressing environmental injustices. The team composition reflects this community-centered approach, including environmental scientists, hardware engineers, technologists, community champions, local organizations, and affected residents as core stakeholders rather than peripheral consultees.

HRIA Framework Alignment:
- **Purpose & Context:** The system addresses documented discrimination in environmental governance, where marginalized communities lack evidence to support their concerns about pollution and climate impacts.
- **Effects of the system:** Benefits are explicitly designed to empower historically marginalized communities, particularly those in informal settlements and rural areas, by providing them with data ownership and advocacy tools.
- **Empowering affected communities:** Community members serve as sensor hosts, data interpreters, and advocates, with genuine decision-making power in sensor placement and use of findings.
- **Team composition:** The team includes diverse expertise (technical, social, environmental) and meaningful representation from affected communities throughout the process.

Key Human Rights Considerations
The initiative explicitly addresses environmental justice as a human rights issue, recognizing that access to environmental information is fundamental to dignity, health, and democratic participation. Team composition ensures that those most affected by environmental harms have agency in data collection and use.

2 **Stage 2: Defining System Requirements**

System requirements emerged from participatory mapping sessions and community dialogues rather than top-down technical specifications. Requirements include real-time monitoring capabilities, offline functionality for areas with limited connectivity, solar power options for off-grid locations,and various data access methods (APIs, visual displays, reports) and protection for sensor host anonymity.

HRIA Framework Alignment:

- **Involving affected communities:** Requirements definition involved extensive community consultation, with separate sessions for different demographic groups to ensure all voices were heard.
- **Explainability considerations:** The system provides explanations through multiple formats—visual air quality indices, written reports, and community presentations—tailored to different audiences and literacy levels.
- **Ecosystem of values:** The initiative balances technical accuracy with accessibility, privacy protection, transparency, and community agency, making conscious trade-offs that prioritize human rights over purely technical optimization.

Key Human Rights Considerations

Requirements prioritize dignity and agency for affected communities. Features like anonymization for sensor hosts, offline capabilities for marginalized areas, and multiple access methods ensure that system design serves justice rather than creating new barriers.

3 ## Stage 3: Data Discovery

Data discovery combines technical sensor measurements with community knowledge through participatory mapping, focus group discussions, and key informant interviews. The process involves communities in identifying what data to collect, where to collect it, and how to interpret findings. Multiple data sources include ground sensors, satellite imagery, drone data, meteorological information, and qualitative community insights.

HRIA Framework Alignment:

- **Data origin:** Data collection respects community consent and privacy, with clear agreements about data use and ownership. Sensitive information is anonymized to protect sensor hosts.
- **Data bias:** The participatory approach explicitly addresses historical bias in environmental monitoring by including communities and geographic areas typically excluded from official data collection.
- **Documentation:** All data sources, collection methods, and processing steps are documented transparently, with findings shared back to communities in accessible formats.

Key Human Rights Considerations

The data discovery process treats community knowledge as equally valid to technical measurements. Participatory mapping ensures that communities define pollution sources and priorities rather than having external definitions imposed. This approach addresses historical injustices in environmental data collection.

4 Stage 4: Selecting and Developing a Model

AI models are developed to serve community-identified needs: predicting pollution events for early warning systems, filling data gaps to maintain evidence continuity, and making complex data accessible through visualization and communication tools. Model selection prioritizes interpretability and community utility over technical sophistication.

HRIA Framework Alignment:

- **Model type and explainability:** Models prioritize explainability appropriate to community contexts, with visual outputs and clear communication about uncertainty and limitations.
- **Fairness aspects:** The initiative explicitly considers how environmental impacts affect different community groups (women, children, elderly) and ensures that AI models account for these differential impacts.
- **Environmental impact:** Solar-powered sensors and locally sourced components minimize the environmental footprint of the monitoring system itself.

Key Human Rights Considerations: Model development serves community empowerment rather than technical optimization. AI enhances rather than replaces community knowledge, providing tools for advocacy and self-determination rather than external control.

5 Stage 5: Testing and Interpreting Outcome

Testing involves both technical validation and community feedback. Communities evaluate whether the system meets their needs, provides useful information, and supports their advocacy goals. Outcomes are interpreted collaboratively, with community members trained to understand and communicate findings. Success is measured by community empowerment and environmental improvements rather than purely technical metrics.

HRIA Framework Alignment:

- **Testing Context and Outcomes:** Testing occurs in real community contexts with actual users, incorporating feedback from diverse community members about system utility and accessibility.
- **Operation Manual:** Training materials are developed in local languages with visual aids, and community members are trained to operate and interpret the system independently.

Key Human Rights Considerations
Testing evaluates whether the system genuinely empowers communities to advocate for their environmental rights. Community feedback shapes system refinements, ensuring that technical performance serves human dignity and agency.

6 **Stage 6: Deployment & Post–Deployment Monitoring**

Deployment involves comprehensive community training, ongoing support for sensor hosts, and continuous adaptation based on community feedback. The initiative includes safety protocols for sensor hosts, regular check-ins, and multiple channels for community input. Long-term sustainability is built through local capacity development and peer learning networks.

HRIA Framework Alignment:
- **Deployment:** Communities have genuine agency to delay or modify deployment based on their assessment of benefits and risks. Deployment includes robust support systems and safety measures for participants.
- **Monitoring:** Continuous monitoring includes both technical performance and community impact, with mechanisms for communities to report concerns or suggest improvements. Success is measured by community empowerment and environmental justice outcomes.

Key Human Rights Considerations
Post-deployment monitoring ensures that the system continues to serve community needs rather than becoming extractive. Regular community feedback loops maintain community ownership and adapt the system to changing needs and contexts.

Integrated Analysis: Human Rights Throughout the AI Lifecycle

The sensors.AFRICA case study demonstrates how human rights considerations can be integrated throughout the AI lifecycle rather than added as an afterthought. Several key principles emerge:

— **Community agency:** At every stage, affected communities have genuine decision-making power rather than tokenistic consultation. This agency extends from initial problem definition through ongoing system adaptation.

— **Justice-oriented design:** Technical choices consistently prioritize community empowerment and environmental justice over technical optimization or efficiency metrics. Participatory Knowledge Creation: The initiative treats community knowledge as equally valid to technical expertise, creating collaborative knowledge production rather than extractive data collection.

— **Adaptive implementation:** System design and implementation adapt continuously based on community feedback, ensuring that the AI serves evolving community needs rather than static technical specifications.

— **Sustainability through ownership:** Long-term sustainability is built through community ownership and capacity development rather than external dependency. The sensors.AFRICA experience demonstrates that AI can serve human rights and environmental justice when developed with genuine community participation throughout the lifecycle. This approach results in more robust, sustainable, and effective systems that empower rather than marginalize affected communities.

About the case study and author

This case study analyzes research conducted by sensors.AFRICA, incubated by Code for Africa, examining environmental pollution across African cities and communities between 2016-2025.

Alicia Olago is an environmental scientist and seasoned researcher with over a decade of experience in sustainable development projects in Eastern Africa and is currently CfA's Senior Product Manager at sensors.Africa. She leads a team of Hardware Engineers and Technologists in a citizen science initiative, utilizing sensors to monitor air, water & sound pollution, and radiation among other environmental hazards, to provide citizens & civic watchdogs actionable information on their cities & communities in the continent.

Other contributors to this case study are Caitlin Kraft-Buchman, Emma Kallina, and Sofia Kypraiou, authors of the original *Framework to AI Development: Integrating Human Rights Considerations Along the AI Lifecycle* upon which the Toolbox structure is based. Additional contributors are Amina Soulimani and Pilar Grant, from Women at the Table and the <AI & Equality> Human Rights Initiative.