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Co-Creating AI for Agriculture: Nigeria's Nsukka Yellow Pepper Project

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Introduction

In the rural community of Nsukka in southeastern Nigeria, women farmers had cultivated the unique Nsukka Yellow Pepper for generations. Known worldwide for its distinctive aroma, this pepper represented both cultural heritage and economic opportunity. But climate change was threatening everything. Strange diseases were destroying crops overnight, water management was becoming increasingly difficult, and farmers were beginning to suspect each other of sabotage when plants appeared cut and damaged each morning.

What happened next challenges conventional approaches to the development of agricultural AI. Rather than arriving with pre-designed solutions, a team of researchers, engineers, and social scientists came with a different question: "What do you need?" The answer would reshape their understanding of both technology and community development, leading to innovations that emerged from the soil up—literally and figuratively.

The Nsukka Yellow Pepper project, part of the broader "Engendering Innovation" initiative under the AI for Development Africa program, demonstrates how artificial intelligence can serve agricultural communities when developed through genuine co-creation rather than top-down technology transfer. Professor Joel Nwakaire, who supervised the initiative as the Project Officer, emphasizes that this was "not a research-driven ideology, but a project that was co-created by identifying and prioritizing the needs of the people."

The genesis: From agricultural crisis to community innovation

The project emerged from a recognition that previous technology interventions in African agriculture had failed to bridge the gap between what researchers developed and what farmers actually needed. Women, who comprise approximately 70% of agricultural production in rural Africa, were particularly underserved by existing technology solutions that often reflected the priorities of developers rather than end users.

The Nsukka Yellow Pepper farmers faced multiple interconnected challenges:

- **Mysterious crop diseases** that appeared overnight, destroying entire sections of farmland.
- **Water management difficulties** exacerbated by climate change.
- **Lack of real-time information** about pest and disease detection.
- **Community tensions** arising from suspicions of sabotage when crops were found damaged.
- **Limited access to extension services** and market information.

Traditional agricultural extension services were inadequate to address these challenges. The farmers possessed substantial indigenous knowledge about their crops and environment, but lacked tools for real-time monitoring and early intervention. Most critically, they had no voice in determining what technological solutions might actually help them.

Building trust through dialogue: The community-centered approach

The breakthrough came through what the team calls "community dialogue"—a participatory approach that fundamentally reordered the relationship between technology developers and end users. Rather than consulting communities about predetermined solutions, the process began with creating safe spaces where farmers could articulate their own understanding of problems and potential solutions.

Separate, Safe Spaces for Authentic Voices

The team made a crucial decision to facilitate separate dialogue sessions based on gender and age, ensuring balanced representation while creating safe spaces where women could speak openly. This wasn't merely a matter of inclusion—it was essential for understanding the full scope of agricultural challenges.

"You could see that the key outcome is that these women could speak freely about their needs, about how they even manage the current challenges in the farm, showing that they already have capacity unlike how we look at them as those who do not have the capacity," explains Professor Nwakaire of the African Technology Policy Studies Network (ATPS).

These sessions revealed several critical insights:

- **Women possessed sophisticated indigenous knowledge** about crop management, pest identification, and adaptive strategies.
- **Different community members prioritized different challenges**—what researchers initially saw as the primary problem wasn't necessarily what farmers identified as most urgent.
- **Social tensions around crop damage** were undermining community cohesion and needed to be addressed alongside technical solutions.
- **Trust building** was essential before any technology intervention could be successful.

Co-Identification of Priorities

Through this participatory process, farmers identified their three highest priority needs:

1. **Real-time pest and disease detection**—not just identification after damage occurred, but early warning systems that could prevent losses.
2. **Efficient water management**—tools to optimize irrigation timing and water use.
3. **Soil information and fertilizer optimization**—better understanding of soil conditions to improve input efficiency

Co-creating technical solutions

Critically, farmers specified that they didn't need help identifying diseases once they appeared—they already possessed that knowledge. What they needed was early detection of pest activity, particularly the mysterious cutting that was happening at night and causing community suspicions.

The technological solutions that emerged from this participatory process were unlike anything that would have been developed through conventional agricultural technology approaches. Each innovation directly addressed farmer-identified priorities while building on existing indigenous knowledge.

The Real-Time Pest Detection System

The centerpiece innovation was a solar-powered, real-time pest detection system that the community had never seen before. This standalone system used:

- **Raspberry Pi mini-computer** running locally (not cloud-dependent).
- **Dual 18-amp, 12-volt batteries** for reliable power.
- **Camera systems** that monitored crops continuously.
- **SMS alert capabilities** to notify farmers immediately of detected threats.

The system was designed to function as a "community farm" model—one installation that would monitor a representative plot, with any alerts prompting immediate treatment across all individual farms in the area. This approach reflected both resource constraints and the collective decision-making structure the community preferred.

The most dramatic validation of this system came when it solved the mystery that was dividing the community. Through images stored in the system's memory, farmers discovered that their crops weren't being sabotaged by neighbors—they were being cut by ants that came at night. This revelation not only prevented a brewing community crisis but demonstrated the power of evidence-based problem-solving.

Water Management Innovation

Responding to farmers' need for efficient water management, the team developed an SMS-based irrigation system that allowed farmers to control irrigation remotely. The system included:

- **Automated irrigation** using gravity flow and solar-powered mechanical valves.
- **SMS control capabilities** allowing farmers to activate irrigation from their homes.
- **Soil moisture sensors** providing real-time feedback about soil conditions.
- **Water level monitoring** to optimize irrigation timing and duration.

This innovation reduced water usage from 5,000 to 2,000 liters per hectare—a dramatic improvement in efficiency that farmers could immediately quantify and appreciate.

The E-Extension App: Community-Driven Support

As the technical systems were deployed and farmers became familiar with them, they identified another need: ongoing support and farm management assistance. This led to the development of "APWENFarm," an e-extension app that reflected farmers' own assessment of what additional support they needed.

Key features included:

- **Offline functionality** that synchronized when network connectivity was available.
- **Expert consultation** with agricultural specialists available to answer farmer questions.
- **Farm management tools** that helped farmers track inputs, expenses, and yields.
- **Mathematical integration** that calculated total expenditures and helped farmers make informed selling decisions.

This app addressed a critical gap that farmers themselves identified: they often forgot what inputs they had applied to their farms and lacked tools to calculate whether they were making a profit.

Integrating social and technical innovation

Perhaps the most significant aspect of the Nsukka project was its recognition that technology deployment must be integrated with broader social and economic empowerment. The participatory development process didn't end with technical solutions—it continued through capacity building and institutional development.

Cooperative Formation

As trust built through the co-creation process, the community decided to form a cooperative society. This wasn't an externally imposed requirement but emerged from farmers' own assessment of how they could collectively benefit from the technological innovations and strengthen their market position. The cooperative provided several benefits:

- **Collective ownership** of expensive technical equipment.
- **Shared learning** as farmers trained each other on system use.
- **Market power** through collective selling and input purchasing.
- **Sustained maintenance** of technical systems through shared responsibility.

Training and Capacity Building

The project included comprehensive training components, but these too were co-designed with farmers rather than imposed externally. Training covered:

- **Technical system operation** and basic maintenance.
- **Data interpretation** and decision-making based on sensor outputs.
- **Collective problem-solving** approaches for ongoing challenges.
- **Business planning** using the farm management tools.

This capacity building ensured that farmers weren't dependent on external technical support for ongoing system operation and could adapt the tools to their evolving needs.
The co-creation approach wasn't without challenges, but the participatory framework provided mechanisms for identifying and addressing problems as they emerged.

Challenges and adaptive solutions

Building initial trust

Some farmers were initially skeptical of external interventions, having experienced previous projects that extracted information without providing meaningful benefits. The team addressed this through:

- **Extended engagement** with multiple community meetings before any technology deployment.
- **Transparent communication** about project goals, funding, and expected outcomes.
- **Demonstration of respect** for indigenous knowledge and farmer expertise.
- **Commitment to community ownership** of both data and technology.

Technical adaptation to local conditions

Standard agricultural technology often fails in African contexts due to power, connectivity, and maintenance constraints. The co-creation process helped identify these challenges early and develop appropriate solutions:

- **Solar power systems** using locally sourced components
- **Standalone operation** that didn't require constant internet connectivity
- **Simple, robust designs** that farmers could maintain themselves
- **Local partnership development** for ongoing technical support

Gender-Responsive Implementation

Ensuring that technology benefits reached women farmers required intentional design choices throughout the process:

- **Separate consultation sessions** to ensure women's voices were heard.
- **Technology design** that accounted for women's specific agricultural responsibilities.
- **Training programs** that accommodated women's time constraints and learning preferences.
- **Cooperative structures** that included women in leadership roles.

Impact beyond technology: Transforming agricultural development

The Nsukka Yellow Pepper project's impact extends far beyond the technical innovations themselves. By demonstrating that farmers possess sophisticated knowledge and can be genuine partners in technology development, the project has influenced broader approaches to agricultural development.

- **Community Empowerment**
  Farmers report increased confidence in their ability to advocate for their needs and participate in agricultural development initiatives. The participatory process validated their knowledge and gave them tools to document and communicate their experiences to outside actors.

- **Sustainable Technology Adoption**
  Because farmers were involved in designing the technical solutions, adoption rates were high and sustained. The community took ownership of maintaining and adapting the systems rather than waiting for external technical support.

- **Model for Replication**
  The co-creation methodology developed through the Nsukka project has been documented and shared with other agricultural development initiatives across Africa. The emphasis on "design by inclusion" has influenced policy discussions about agricultural technology deployment.

- **Academic and Policy Impact**
  The project has contributed to academic literature on participatory technology development and influenced policy discussions about gender-responsive agricultural innovation. Research publications have documented the methodology and outcomes, providing evidence for alternative approaches to agricultural AI development.

Looking Forward: Scaling Co-Creation

The Nsukka Yellow Pepper project demonstrates that AI can serve agricultural communities when developed through genuine co-creation rather than top-down technology transfer. As the approach expands to other crops and regions, each new deployment offers opportunities to refine the methodology while adapting to different agricultural, social, and cultural contexts.

The project's success stems not from technological sophistication alone, but from recognizing that agricultural AI is ultimately about human dignity, community empowerment, and the right to food security. The farmers in Nsukka who no longer suffer mysterious crop losses, who have improved their water efficiency, and who have gained tools for better farm management represent the true measure of AI's potential to serve human rights and agricultural justice.

The yellow peppers continue to grow in Nsukka, but now they're monitored by systems that emerged from the soil up—technologies that reflect the knowledge, priorities, and agency of the women who tend them.

Mapping the AI Lifecycle HRIA Framework for the Nsukka Yellow Pepper Project

1 Stage 1: Objective and Team Composition

The project began with community dialogue rather than predetermined objectives. Through separate, safe sessions with women farmers, researchers learned that the primary need wasn't technology deployment but community-identified solutions to crop losses and water management challenges. The team composition evolved to include farmers as co-developers, not just end users.

HRIA Framework Alignment:

- **Purpose & Context:** The system emerged from community-identified problems rather than external assumptions about agricultural needs.
- **Effects of the System:** Benefits were explicitly designed to empower women farmers who comprise 70% of agricultural production but are often excluded from technology development.
- **Empowering Affected Communities:** Farmers served as co-developers throughout the process, with genuine decision-making power in system design and implementation.
- **Team Composition:** The team included diverse expertise (technical, social, agricultural) and meaningful representation from affected communities.

Key Human Rights Considerations:

The initiative explicitly addressed agricultural justice as a human rights issue, recognizing that food security and livelihood sustainability are fundamental to dignity. Team composition ensured that those most affected by agricultural challenges had agency in solution development.

2 Stage 2: Defining System Requirements

System requirements emerged from participatory mapping and community priority-setting rather than technical specifications. Requirements included: real-time pest detection (not just identification), SMS-based remote irrigation control, offline functionality, community farm monitoring model, and integration with existing indigenous knowledge systems.

HRIA Framework Alignment:

- **Technical equirements Driven by Community Needs:** The choice of smartphone-based technology and 3D-printed adapters directly addressed the resource constraints identified by local partners. Requirements prioritized accessibility and local sustainability over technical sophistication.
- **Ecosystem of Values:** The team balanced multiple values - diagnostic accuracy (99% for parasite detection), speed (5 seconds inference time), accessibility (smartphone compatibility), and sustainability (locally manufacturable components).
- **Explainability:** The system was designed to provide decision support for healthcare workers rather than replace human judgment, maintaining transparency about AI capabilities and limitations.
- **Privacy Considerations:** Requirements included strict data anonymization protocols and local processing capabilities to protect patient privacy from the design stage.

Key Human Rights Considerations:

Requirements prioritized dignity and agency for women farmers. Features like community ownership, SMS communication, and building on indigenous knowledge ensured that system design served empowerment rather than creating new dependencies.

3 Stage 3: Data Discovery

Data discovery combined technical sensor measurements with community knowledge through participatory mapping, farmer expertise, and collaborative problem identification. The process involved communities in identifying what data to collect, how to interpret findings, and how to use information for collective benefit.

HRIA Framework Alignment:

- **Data Origin:** Data collection respected community consent and ownership, with clear agreements about data use. The community farm model ensured collective benefit from information gathering.
- **Data Bias:** The participatory approach explicitly addressed historical bias in agricultural development by centering women farmers' knowledge and priorities.
- **Documentation:** All data sources, collection methods, and interpretation processes were documented transparently, with findings shared back to communities in accessible formats.

Key Human Rights Considerations:

The data discovery process treated indigenous agricultural knowledge as equally valid to technical measurements. Participatory approaches ensured that communities defined agricultural priorities rather than having external definitions imposed.

4 Stage 4: Selecting and Developing a Model

AI models were developed to serve community-identified needs: real-time pest detection for early warning, soil moisture monitoring for irrigation optimization, and farm management tools for economic empowerment. Model selection prioritized interpretability and community utility over technical sophistication.

HRIA Framework Alignment:

- **Model Type and Explainability:** Models prioritized explainability appropriate to farmer contexts, with visual outputs and clear communication about system capabilities and limitations.
- **Fairness Aspects:** The initiative explicitly considered how agricultural challenges affect different community groups (women, men, different age groups) and ensured that AI models supported gender equity.
- **Environmental Impact:** Solar-powered sensors and locally sourced components minimized environmental footprint while supporting local economies.

Key Human Rights Considerations:

Model development served community empowerment rather than technical optimization. AI enhanced rather than replaced indigenous knowledge, providing tools for agricultural justice and self-determination.

5 Stage 5: Testing and Interpreting Outcome

Testing involved both technical validation and community feedback. Farmers evaluated whether the system met their needs, provided useful information, and supported their agricultural goals. Outcomes were interpreted collaboratively, with community members trained to understand and use findings for collective benefit.

HRIA Framework Alignment:

- **Testing Context and Outcomes:** Testing occurred in real agricultural contexts with actual users, incorporating feedback from diverse community members about system utility and effectiveness.
- **Operation Manual:** Training materials were developed collaboratively, and community members were trained to operate and interpret the system independently.

Key Human Rights Considerations:

Testing evaluated whether the system genuinely empowered farmers to improve their livelihoods and agricultural practices. Community feedback shaped system refinements, ensuring that technical performance served human dignity and agency.

6 Stage 6: Deployment & Post-Deployment Monitoring

Deployment involved comprehensive community training, formation of cooperative societies for collective ownership, and continuous adaptation based on farmer feedback. The initiative included ongoing support systems, peer learning networks, and integration with existing community structures for sustainability.

HRIA Framework Alignment:

- **Deployment:** Communities had genuine agency to modify deployment based on their assessment of benefits and effectiveness. Deployment included robust support systems and capacity building for participants.
- **Monitoring:** Continuous monitoring included both technical performance and community impact, with mechanisms for farmers to report concerns or suggest improvements. Success was measured by agricultural productivity and community empowerment outcomes.

Key Human Rights Considerations:

Post-deployment monitoring ensured that the system continued to serve community needs rather than becoming extractive. Regular community feedback loops maintained farmer ownership and adapted the system to evolving agricultural and social needs.

Integrated Analysis:
Human Rights Throughout the AI Lifecycle

The Nsukka Yellow Pepper project demonstrates how human rights considerations can be integrated throughout the AI lifecycle rather than added as an afterthought. Several key principles emerge:

- **Community Co-Development:** At every stage, farmers had genuine decision-making power rather than tokenistic consultation. This agency extended from initial problem definition through ongoing system adaptation.

- **Justice-Oriented Design:** Technical choices consistently prioritized community empowerment and agricultural justice over technical optimization or efficiency metrics.

- **Participatory Knowledge Creation:** The initiative treated indigenous agricultural knowledge as equally valid to technical expertise, creating collaborative knowledge production rather than extractive data collection.

- **Adaptive Implementation:** System design and implementation adapted continuously based on farmer feedback, ensuring that AI served evolving community needs rather than static technical specifications.

- **Sustainability Through Ownership:** Long-term sustainability was built through community ownership, cooperative formation, and capacity development rather than external dependency.

The Nsukka experience demonstrates that AI can serve human rights and agricultural 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

This case study analyzes research conducted by the African Technology Policy Studies Network (ATPS) in collaboration with the International Centre of Insect Physiology and Technology (icipe), Kenya and Kumazi Hive (Ghana), focused on Strengthening the Capacity of Women and Marginalized Communities in Africa's Agriculture and Food Systems to Harness the Potentials of Artificial Intelligence Technology in alliance with the Artificial Intelligence for Agriculture and Food Systems (AI4AFS) project "Using Artificial Intelligence to Enhance the Production, Marketing, and Management of Nsukka Yellow Pepper in Nigeria" led by Professor Chinenye Anyadike of the Association of Profession Women Engineers (APWEN), with partners from University of Nigeria, Nsukka, and Educare Nigeria Limited, Nigeria between 2022–2024.

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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.