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The Potential of AI Extension Agents to Support Women Home Gardeners in Ghana: An HCI4D-Grounded Assessment

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ABSTRACT

Home gardening is a vital livelihood and food security strategy for low-income households in Ghana, with women serving as the primary managers of these spaces. However, gender disparities in extension services, limited digital access, and an overstretched public agricultural system restrict women's ability to obtain timely agronomic advice. Artificial Intelligence–enabled advisory systems, or AI Extension Agents, offer new possibilities for providing personalized, real-time support at scale. Yet their deployment in low-resource settings raises key concerns related to digital equity, algorithmic fairness, cultural relevance, and user empowerment. This paper applies the Human–Computer Interaction for Development (HCI4D) framework to assess the potential, risks, and design requirements of AI advisory tools for Ghanaian women home gardeners. Through synthesis of empirical literature, gender-and-technology studies, and emerging AI-in-agriculture initiatives, the analysis highlights how AI Extension Agents can help close knowledge gaps and complement human extension systems. However, these benefits depend on participatory design processes that center women's needs, support multiple literacy levels, integrate local agricultural knowledge, and incorporate strong human-in-the-loop validation. We propose a four-pillar, community-grounded AI extension ecosystem that aligns technological innovation with equity and social justice.

Keywords: AI in agriculture, Women farmers, Home gardening, HCI4D, Digital inclusion, Agricultural extension

INTRODUCTION

Agricultural extension systems face mounting pressure to serve growing populations with shrinking resources. In Ghana, a single extension agent supports approximately 1,500 farmers, nearly four times the Food and Agriculture Organization's recommended 1:400 ratio (Ocran et al., 2024; Sha et al., 2025). This crisis disproportionately impacts women home gardeners who sustain household food production yet receive systematically

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fewer extension visits than their male counterparts (Ankrah et al., 2020). As climate variability intensifies and urban food insecurity deepens, the gap between information needs and extension capacity continues to widen (Ogwu et al., 2024).

Artificial Intelligence-enabled agricultural advisory systems, termed AI Extension Agents, offer opportunities to democratize agronomic knowledge. Through conversational interfaces, image-based diagnostics, hyper-local weather analytics, and multilingual voice support, these tools deliver personalized guidance at scales impossible for human systems alone (Abdulhamid et al., 2025; Dutra, 2025; Paterson, 2025; Somitsch, 2024). Early African deployments demonstrate potential for real-time pest identification, climate-smart recommendations, and smartphone-accessible advice (Chavula et al., 2024; Nnanguma, 2025; Okafor & Akanwa, 2025; Tamasiga et al., 2023).

However, technology alone cannot overcome structural inequalities independently (Theeuwen et al., 2021). Sub-Saharan African women face the world's largest digital gender gap, with 190 million lacking mobile phone access and far fewer using digital agricultural services than men (Herbert, 2017). Low literacy rates, time poverty from unpaid care work, and sociocultural norms limiting technology adoption create compounding barriers (Abdulkareem et al., 2024; Goodluck et al., 2016). Without intentional equity-focused design, AI systems risk deepening existing divides while concentrating benefits among already-advantaged users (Umoke et al., 2025).

This paper addresses: How can AI Extension Agents be designed to genuinely empower Ghanaian women home gardeners rather than reproducing digital inequalities? We employed the Human-Computer Interaction for Development (HCI4D) framework to systematically analyze opportunities, risks, and design imperatives. This approach foregrounds contextual fit, participatory design, inclusivity, empowerment, and sustainability, principles essential for responsible AI deployment in low-resource contexts.

LITERATURE REVIEW

Women's Centrality in Ghana's Home Gardening System

Home and backyard gardening are key livelihood strategies for low-income and peri-urban households in Ghana, supporting nutrition, income, and climate resilience (Adusei et al., 2025; Asante et al., 2024; Boakye-Achampong et al., 2012). Women are the primary managers of these spaces, overseeing soil preparation, crop selection, planting, watering, input procurement, and pest management, contributing significantly to household food security and local food systems (Adusei et al., 2025; Maredia et al., 2023).

Despite this central role, women gardeners remain undervalued in agricultural development frameworks that prioritize commercial farming. Asante et al. (2024) revealed that women possess sophisticated knowledge of crop rotation, indigenous varieties, water conservation, and ecological pest control. This expertise is rarely recognized in formal extension programs (Msengana et al., 2025). These omissions reflect broader gender biases that marginalize women's agricultural contributions.

Structural Barriers to Agronomic Information Access

Women face intersecting barriers that limit their access to agricultural knowledge and support services:

Gender Disparities in Extension Access

Ankrah et al. (2020) found that women receive significantly fewer extension visits than men, reflecting both explicit gender bias and implicit assumptions about household farming dynamics. Similarly, Abebe and Mulu (2017) assert that extension programs frequently target male household heads, bypassing women who perform most daily garden management.

Time Poverty and Mobility Constraints

Women's disproportionate responsibility for childcare, meal preparation, water collection, and other domestic tasks severely limits their ability to attend agricultural trainings. It also restricts their capacity to travel to extension offices (Adusei et al., 2025; Amri and Kimaro, 2010). Group meetings scheduled during daylight hours conflict with peak garden work periods and household obligations.

Digital Access Inequalities

Sub-Saharan Africa exhibits the world's largest digital gender gap, with women substantially less likely than men to own smartphones, access mobile data, or use digital agricultural services (Herbert, 2017). Cost barriers, lower literacy rates, and social norms restricting women's technology use create compounding disadvantages. Among rural women, smartphone penetration remains particularly low, while feature phone capabilities limit access to app-based services (Evans, 2018; Potnis, 2016).

Low Literacy and Language Barriers

Many women home gardeners have limited formal education, constraining their ability to engage with text-based agricultural information (Huyer et al., 2021). Extension materials produced primarily in English exclude women who are more comfortable with local languages. These barriers are compounded when technical terminology requires specialized vocabulary (Dodson et al., 2013).

Crisis in Ghana's Agricultural Extension System

Ghana's Ministry of Food and Agriculture operates under severe resource constraints, with extension-to-farmer ratios nearing 1:1,500, far beyond functional limits (Ocran et al., 2024; Sha et al., 2025). Overwhelming caseloads, inadequate transportation, outdated materials, and limited access to new research further weaken service delivery. Home gardeners, already deprioritized relative to commercial farmers, are disproportionately affected.

These constraints lead to delayed responses to pest outbreaks, generic recommendations unsuited to diverse garden conditions, and minimal follow-up support. For women managing small, resource-limited plots with multiple crops, such generalized advice is of limited value (Howard, 2003; Schroeder, 1993). This entrenches knowledge gaps, reduces productivity, and deepens food insecurity.

Emergence of AI in African Agricultural Systems

Across Sub-Saharan Africa, AI-enabled agricultural advisory tools are expanding rapidly through conversational chatbots, mobile applications, voice assistants, remote sensing systems, and image recognition technologies (Abdulhamid et al., 2025; Somitsch, 2024). These systems employ machine learning for plant disease diagnosis, natural language processing for multilingual support, predictive analytics for weather forecasting, and computer vision for pest identification.

Notable examples include FarmerAI platforms offering real-time crop diagnostics and ClimateAi tools delivering hyper-localized forecasts (Paterson, 2025). Additionally, System Analysis Program (SAP) generative AI systems provide conversational guidance to support farmer decision-making (Dutra, 2025). Early evidence shows these tools can diagnose diseases faster than human agents, operate continuously, and scale to millions of users. However, deployment remains uneven, concentrated in commercial and male-dominated farming sectors. Home gardening and women's specific knowledge needs, remain largely excluded, presenting both a critical gap and an opportunity for equity-focused AI design.

THEORETICAL FRAMEWORK

To analyze AI Extension Agent potential while centering equity and empowerment, we employed the Human-Computer Interaction for Development (HCI4D) framework. The HCI4D emerged from recognition that technology design principles developed for high-resource contexts often fail, or cause harm, when applied to low-resource environments (van Biljon, 2018). The framework emphasizes that meaningful technology adoption requires alignment with local realities, user needs, and power dynamics.

Core HCI4D Principles

Contextual Fit: Technologies must reflect the socio-cultural, infrastructural, economic, and institutional realities of deployment contexts. For Ghanaian women gardeners, this means designing for intermittent electricity, limited data connectivity, shared device usage, oral information cultures, and household power dynamics that may restrict women's technology access (Abdulai et al., 2023; Atanga, 2020).

Participatory Design: Users, particularly marginalized groups, must actively co-define problems and co-create solutions rather than serving as passive recipients of predetermined technologies (Evans, 2018; Farayola et al., 2020). Women gardeners possess intimate knowledge of their information needs, workflow constraints, and social contexts that external designers cannot anticipate. Their participation ensures resulting tools genuinely serve rather than burden them.

Inclusivity and Accessibility: Evans (2018) and Wafula-Kwake et al. (2007) notes that interfaces must accommodate varying literacy levels, languages, abilities, ages, and device types. This requires moving beyond text-heavy smartphone apps toward multimodal systems incorporating voice, images, and offline functionality. Accessibility extends to cost barriers, requiring consideration of data expenses and device affordability.

Empowerment: Technologies should enhance user agency, reduce inequities, and avoid reinforcing existing power imbalances. For women gardeners, empowerment means gaining access to knowledge traditionally monopolized by male extension agents, making autonomous agricultural decisions, and strengthening their recognized expertise within households and communities (Abdulai et al., 2023., Evans, 2018).

Sustainability: Systems must be maintainable within local institutional capacities and community resources. Dependence on external technical expertise or expensive infrastructure creates fragility. Sustainable systems integrate with existing institutions, such as Ghana's Ministry of Food and Agriculture, while building local capacity for ongoing operation and adaptation (Anderson et al., 2019).

Human-in-the-Loop: Hybrid systems combining AI with human expertise promote trust, reduce risks from algorithmic errors, and preserve space for indigenous knowledge and experiential learning. Rather than replacing extension agents, AI should augment their capacity by handling routine inquiries while humans provide complex guidance and relationship-based support (Alabi, 2016).

HCI4D as Analytical Lens

We employ HCI4D principles to evaluate AI Extension Agent opportunities and risks across three dimensions:

1. **Technical Design:** How must AI systems be architectured to function effectively in low-resource contexts with intermittent connectivity, diverse device types, and limited digital literacy?
2. **Social Integration:** How can AI tools align with women's social roles, time constraints, cultural norms, and household dynamics without imposing additional burdens or reinforcing inequalities?
3. **Institutional Embedding:** How should AI systems interface with existing extension services, agricultural cooperatives, women's groups, and government programs to ensure long-term viability and impact?

This multi-dimensional analysis reveals both promising pathways and critical design imperatives for responsible AI deployment.

METHODOLOGICAL APPROACH

This conceptual paper employs an integrative, multi-method analytical approach to evaluate the potential of AI Extension Agents for women home gardeners in Ghana. We began with a systematic synthesis of empirical literature on women's essential yet undervalued roles in Ghanaian agriculture (Asante et al., 2024; Boakye-Achampong et al., 2012), the severe constraints of the national extension system (Ocran et al., 2024; Sha et al., 2025), and the persistent digital gender gap (Herbert, 2017; Ankrah et al., 2020). Concurrently, we assessed real-world AI agricultural advisory platforms, examining their technical capabilities, interaction models, and documented impacts (Somitsch, 2024; Dutra, 2025; Abdulhamid et al., 2025), to map current feasibility. Central to our analysis was the application of the Human–Computer Interaction for Development (HCI4D) framework, which allowed us to interrogate how AI design choices either enable or exclude low-literacy, rural women. We further layered a gender lens, drawing on feminist technology studies (Kim & Lee, 2024; Omotayo et al., 2025) to uncover how AI might reinforce or disrupt entrenched inequities. Finally, we anchored our insights into global development discourse through policy reviews from the World Economic Forum (2025) and IFPRI (Davis et al., 2025). While this conceptual groundwork clarifies design imperatives and ethical risks, it also underscores the urgent need for future participatory, field-based research co-created with Ghanaian women gardeners themselves.

FINDINGS: OPPORTUNITIES THROUGH AN HCI4D LENS

AI Extension Agents provide unattainable individualized guidance through traditional extension systems by using machine learning to assess crop types, growth stages, soil conditions, localized weather patterns, and pest pressures (Abdulai et al., 2023; Somitsch, 2024). These capabilities generate context-specific recommendations for women home gardeners. Real-time image recognition allows gardeners to photograph plant symptoms and receive immediate diagnoses and treatment options, an essential feature for those managing diverse crops in small spaces (Abdulhamid et al., 2025). Hyper-local forecasting further supports irrigation and harvesting decisions, while seasonal alerts improve production timing (Paterson, 2025). From an HCI4D perspective, such tailored support reflects strong contextual fit. However, achieving this requires models focused on Ghana-specific crops, soils, pests, and indigenous practices, rather than generalized global datasets.

AI's natural language processing expands linguistic accessibility, providing support in local languages far beyond the English-dominant materials typical of extension services. Voice-based interfaces allow low-literate users to ask questions and receive spoken responses (Natchev, 2024; Dutra, 2025). Pictorial guides and video demonstrations further reduce text barriers by visually highlighting pest identification and gardening practices. Consistent with HCI4D inclusivity principles, these features make agricultural information usable for women with limited formal education. However, effective deployment requires culturally sensitive conversational design and robust local-language datasets that reflect women's terminology and communication norms across communities (Dodson, 2013).

AI systems also offer women private, stigma-free access to advice, enabling them to seek information without the social pressures common in male-dominated extension settings (Bronson, 2018). Its on-demand nature aligns with women's schedules, while mobile access supports those restricted by childcare, domestic responsibilities, or limited mobility (Amri & Kimaro, 2010). This flexibility advances HCI4D empowerment goals by enhancing autonomous decision-making and strengthening women's authority in household agricultural discussions. As Omotayo et al. (2025) noted, technology-mediated knowledge can disrupt norms that position men as gatekeepers, though true empowerment requires AI tools that respect indigenous practices and validate women's expertise.

A hybrid human–AI extension model further strengthens Ghana's resource-constrained system by allowing AI to handle routine queries, enabling extension agents to focus on complex, relational challenges. AI can triage cases and flag emerging outbreaks for rapid human response, improving system responsiveness and sustainability (Davis et al., 2025). In this model, AI functions as a decision-support partner rather than a replacement, maintaining trust and institutional relevance while expanding reach for women home gardeners.

FINDINGS: RISKS AND CRITICAL DESIGN CHALLENGES

Without deliberate, equity-centered design, AI Extension Agents risk excluding women and low-income gardeners, who often lack smartphones, data affordability, and digital literacy. The advantages are more common among men and wealthier households (Herbert, 2017). Women's limited device access and connectivity can hinder engagement, deepening marginalization if AI becomes the main advisory channel (Dodson, 2013). HCI4D principles demand proactive inclusion: community smartphone hubs, subsidized data plans, women-led digital literacy programs, USSD support for feature phones, and offline functionality.

AI systems can generate confident but incorrect advice, so-called "hallucinations", with serious agronomic or health consequences (Davis et al., 2025; Omotayo et al., 2025). Models focused on Global North data may misread Ghanaian crops or conditions, offering plausible yet harmful guidance (Bacco et al., 2019). Women, with fewer alternative sources, may struggle to discern reliability. HCI4D's human-in-the-loop approach mitigates this by requiring extension agents to validate outputs, flag uncertainties, and incorporate user feedback.

AI trained on commercial farming often misaligns with women's home gardening realities, promoting monoculture over intercropping, assuming access to costly inputs, or ignoring time poverty from domestic labor (Alabi, 2016). Gender bias may appear through male voices, visuals, or language that frames users as (male) household heads, excluding women (Evans, 2018; Wafula-Kwakwa et al., 2007). HCI4D's participatory design mandates women co-create training data and interfaces, using localized datasets and culturally resonant visuals that honor indigenous knowledge (Farayola et al., 2020).

AI tools collect sensitive data, geolocation, garden photos, voice recordings, that could enable surveillance, exploitation, or discrimination (Abdulai et al., 2023). Women may face privacy risks if household members access their data, reinforcing male control. HCI4D empowerment requires transparent, local-language consent; secure storage; user rights to delete data; and bans on third-party sales (Atanga, 2020; Wafula-Kwakwa, 2007).

Finally, overreliance on AI may erode generations of indigenous knowledge and weaken community learning networks (Braimah et al., 2017). HCI4D sustainability means AI should complement, not replace traditional practices. Systems should validate women's knowledge, enable peer exchange, and preserve the relational role of human extension agents.

HCI4D-GROUNDED DESIGN IMPLICATIONS

Effective AI Extension Agents must involve women directly in design, development, and deployment. Co-design should engage women in identifying priority needs, prototyping interfaces, testing language, and evaluating advice (Evans, 2018; Farayola et al., 2020), ensuring solutions reflect real needs, not external assumptions. Such processes must confront power imbalances by creating safe, inclusive spaces where women can freely shape design (Abdulkareem et al., 2024; Anderson et al., 2019), using proven community-based participatory methods from Information and Communication Technologies for Development (ICT4D).

Interfaces must be multimodal and accessible: voice-first with optional text, offline-capable, and available via USSD for feature phones. Local-language support should reflect cultural speech patterns, while image and audio content accommodate low literacy (Dodson, 2013). Systems must minimize data use, support low-end devices, and offer subsidized access to remove economic barriers.

Model data must mirror Ghanaian realities, documenting local crops, pests, indigenous practices, weather patterns, and women's time/resource constraints. Models should recognize intercropping, organic pest control, and water-saving techniques, not just commercial farming. Gender-sensitive design includes women's voices in datasets, visuals of women gardeners, and advice that respects their dual productive and reproductive roles.

AI must align with women's daily rhythms, sending alerts during available hours, acknowledging seasonal workloads, and navigating household decision-making dynamics (Abebe & Mulu, 2017). Transparency about AI limitations builds trust. Systems should explain reasoning behind recommendations, acknowledge uncertainty, and provide feedback options: "Was this advice helpful?" ratings, problem reporting mechanisms, and community discussion forums. Iterative improvement based on user feedback demonstrates responsiveness to women's experiences.

PROPOSED IMPLEMENTATION MODEL

Building on the HCI4D framework, we propose a four-pillar, community-grounded AI extension ecosystem that empowers women gardeners and supports equitable, context-appropriate technology use.

The first pillar, Woman-Centered Digital Inclusion, promotes accessible technology through community smartphone hubs, device lending schemes, peer-led digital literacy programs, and local-language onboarding that prioritizes voice interaction. It also strengthens partnerships with women's agricultural groups to support collective access.

The second pillar, Hybrid AI–Human Support, uses AI for routine diagnostics, planting reminders, weather alerts, and basic pest identification. Extension agents then address complex problems, validate AI outputs, and provide relationship-based support that AI cannot replicate. AI also triages cases, flags emerging outbreaks, and incorporates feedback to improve system performance.

The third pillar, Participatory Model Development, ensures women gardeners contribute local knowledge through community data collection, co-create culturally relevant interfaces, and participate in ongoing evaluation.

The final pillar, Policy and Institutional Integration, embeds the system within Ministry of Food and Agriculture programs while partnering with research institutions and private AI companies to ensure secure, context-appropriate technical development. It also collaborates with civil society organizations, including women's cooperatives and local NGOs, to promote transparency, equitable access, and accountable governance. Recognizing that ethical AI requires shared responsibility across government, civil society, and the private sector, this pillar builds an ecosystem where technological innovation aligns with social justice and advances women's empowerment.

CONCLUSION

AI Extension Agents offer significant potential to support Ghanaian women home gardeners, key yet chronically underserved contributors to household and community food security. These tools can bridge critical agronomic advice gaps that conventional extension systems have long failed to address by delivering personalized, voice-based, image-enabled, and hyper-local advisory services. However, benefits are not automatic. Without equity-centered, HCI4D-informed design, AI risk deepening digital divides or privileging already-advantaged men users. Responsible deployment requires participatory co-design, multimodal interfaces for low-literacy users, models focused on local crops and indigenous practices, human-in-the-loop validation, and strong data protection. When aligned with women's time, norms, and knowledge, AI strengthens agency, not dependency. The proposed four-pillar model integrates technology within community and institutional systems, positioning AI not as a technological fix but as a collaborative, socio-technical tool for equitable, resilient food systems.

DECLARATION OF INTEREST

The authors declare that there are no financial, personal, or institutional conflicts of interest associated with the preparation or publication of this work.

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