Soil health for productivity and climate resilience: a partnership scoping exercise

Public Report on Innovate UK Scoping Project for Climate Smart Agriculture Partnerships: UK-Brazil-Africa

Addressing the *soil fertility and water management* topic area

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Acknowledgements
We gratefully acknowledge funding from Innovate UK under the Climate-Smart Agriculture Partnerships: UK-Brazil-Africa programme; UK Foreign, Commonwealth and Development Office in Nigeria and Ghana for facilitation of connections and support; the National Water Resources Institute, Nigeria, for logistical and partnership development support; the Nigerian Ministry of Water and Sanitation; UNESCO Intergovernmental Hydrological Programme (International Sediment Initiative) for facilitating Dr Yaya and Prof. Blake's connectivity with the wider "*Transforming knowledge for Africa's Future*" agenda, which provided the foundation for this collaboration.

1. Summary of the topic area

Climate-Smart Agriculture (FAO, 2010) is an approach that guides actions to transform food systems towards green and climate resilient practices. It supports reaching internationally agreed goals such as the UN Sustainable Development Goals and the Paris Agreement on Climate Change, and aims to tackle three main objectives (FAO, 2024):

1. Sustainably increasing agricultural productivity and incomes.
2. Adapting and building resilience to climate change.
3. Reducing and/or removing greenhouse gas emissions, where possible.

'Soil health' across its interconnected physical, chemical and biological dimensions underpins the fundamental objectives of Climate-Smart Agriculture (CSA) and sustainable land-water systems. For example, a healthy soil with nutrients balanced to crop types increases agricultural productivity, supporting profitable agribusiness for food and national GDP, e.g. cocoa in Ghana (Läderach et al., 2013). Equally, a soil that is healthy in structure and stability is resilient to hydrological extremes of drought and flood, supporting adaptation and building resilience to climate change, noting summer rainfall extremes have intensified in Nigeria over recent decades, due to climate change (Dike et al., 2020). Building soil organic matter through change in agricultural practices underpins fundamental CSA health dimensions, bringing co-benefits of carbon sequestration and reducing/removing greenhouse gas emissions.

By accelerating the development, adoption and scaling of technologies and practices that promote CSA, sustainable food production systems can be established in Ghana and Nigeria. Evidencing co-benefits of CSA practice to deliver soil health remains, however, a challenge, in part due to costly and time-consuming traditional soil assessment tools but also due to conflicting sectoral perspectives on soil health priorities (e.g. 'carbon for soils or soils for carbon' debate: Moinet et al., 2023). Addressing the soil health assessment challenge supports both grassroots decision making and co-design of policy – policy that is adaptable to local socio-economic, environmental and climate change factors, delivering toward the Food and Agricultural Organisation (FAO) action point of expanding evidence bases for CSA across crops, land types and farming systems.

Effective soil health assessment and water management is critical for the successful implementation of CSA, yet current methods to provide evidence often prove costly and time-consuming, hindering both grassroots decision-making and policy development (Taylor et al., 2023). Our scoping work has identified significant opportunities to leverage technological innovations, such as remote sensing; in-situ and laboratory-based spectroscopy; and AI-driven data analysis, to create rapid, affordable, and accessible soil assessment tools. Furthermore, integrating these technologies with indigenous knowledge systems (e.g. Kelly et al., 2020) enhances the relevance of soil health data. We approached this task from the position that fusion of modern technology and traditional wisdom (e.g. Blake et al. 2020) will engender the development of innovative context-specific CSA strategies, fostering sustainable land

management and supporting the expansion of evidence-based practices across diverse agricultural landscapes.

2. Challenges and barriers to Climate Smart Agriculture in Nigeria and Ghana

Climate-Smart Agriculture (CSA) is widely recognised, politically and institutionally, in Nigeria and Ghana as a vital strategy for enhancing agricultural productivity, resilience, and sustainability in the face of climate change. Policymakers, researchers, and agricultural NGOs increasingly advocate for CSA as a key solution for ensuring food security, enhancing climate resilience, and reducing environmental impacts. Despite this broad appreciation, significant challenges hinder its effective implementation. Key barriers include knowledge gaps, resource limitations, weak policy enforcement, poor strategy coordination, and socio- cultural and environmental constraints. Critical technology gaps, such as inadequate precision farming tools, soil health monitoring technology and real-time agricultural data, further constrain CSA adoption.

The following section outlines the key challenges and opportunities identified by stakeholders in a workshop in December 2024 in Abuja, and in interviews conducted in February and March 2025. The workshop (Figure 1) brought together over 40 participants from 25 organisations across Nigeria, Ghana, and the UK. Workshop perspectives were further enriched by interviews with local NGOs and government consultants working directly with farmers; an international webinar with panel discussion and Q&A; and strategic online meetings with government and research organisations in Brazil. The results highlight critical barriers to the effective implementation of Climate-Smart Agriculture, offering valuable insights into gaps in knowledge, resources, policy, coordination, and technology that hinder resilient and sustainable food production in both countries.

Figure 1: Innovate UK workshop, Abuja, December 2024

2.1 Knowledge Gaps

One of the most significant barriers to CSA adoption in Nigeria and Ghana, and more broadly worldwide, is a lack of adequate awareness and knowledge in both political and practical terms. Policymakers and farmers often have limited understanding of CSA principles and how they differ from traditional farming practices:

- *Transition from Traditional to CSA Practices:* Participants reported that many farmers in both countries are unfamiliar with CSA techniques and their potential benefits, leading to reluctance to adopt new methods. Traditional practices remain dominant, and the transition to CSA is slow due to a lack of practical demonstrations and extension services.
- *Crop-Specific Knowledge*: CSA strategies must be adapted to different agroecological zones and crop types. However, there is inadequate evidence and knowledge about how to customise CSA techniques for specific crops, leading to inefficiencies in implementation and/or a less than optimum approach for specific contexts.
- *Soil Health and Resource Management*: Farmers lack sufficient understanding of soil health, optimisation of fertiliser use, and sustainable land management practice tailored to their own context. This knowledge gap contributes to a lack of soil conservation and reduced agricultural productivity.
- *Integration of Indigenous and Modern Knowledge*: Many small-scale farmers draw on ancestral farming practices that align with CSA principles, yet the lack of identification and integration of conceptual crossovers between these and modern techniques often discourages them from adopting CSA methods.
- *Capacity Building and Training:* There are limited training opportunities for farmers, extension workers, and government officials on CSA practices. Without adequate training and a broad and shared understanding of context-specific needs and opportunities, stakeholders struggle to implement CSA effectively.
- *Awareness and Information Dissemination*: Smallholders, who form the majority of agricultural producers, often lack access to CSA information. The absence of structured information-sharing platforms further exacerbates this problem.
- *Data Availability for Decision-Making:* Limited access to real-time agricultural data - such as soil health indicators, weather forecasts, and market trends - prevents informed decision-making. Farmers struggle to implement CSA effectively without reliable and accessible data.

2.2 Resource Gaps

Participants reported that the adoption of CSA in Nigeria and Ghana is constrained by inadequate financial, technological, and infrastructure resources. Farmers and supporting institutions lack the necessary tools to implement CSA effectively.

- *Financial Constraints:* Smallholder farmers, who form the majority of agricultural producers, were known to face significant financial barriers, including:
  - Limited access to credit due to stringent lending conditions and the need for substantial collateral.
  - Insufficient public and private investment in CSA projects.

- High costs of CSA tools and technologies.

- *Inadequate CSA Technologies:* Farmers lack access to advanced CSA tools, including precision farming technologies, soil health monitoring technologies and irrigation systems. Research laboratories remain underfunded and poorly equipped.
- *Infrastructure Challenges:* Poor rural infrastructure, including inadequate irrigation systems and underdeveloped road networks, restricts farmers' ability to adopt Climate-Smart Agriculture technologies, and hamper access to markets that can afford CSA products
- *Limited Access to Agricultural Inputs:* The high cost of essential CSA inputs - such as organic fertilisers and climate-resilient seeds - poses a significant barrier to effective implementation.
- *Challenges in Governance and Resource Allocation:* Government resources for CSA initiatives are often misallocated due to lack of transparency and/or accountability, and inefficiencies, leading to poor project implementation and limited impacts.

2.3 Policy and Regulatory Gaps

Weak policies and sub-optimal governance structures pose major obstacles to CSA adoption in Nigeria and Ghana. While CSA policies exist, their implementation remains challenging due to poor enforcement and a lack of stakeholder involvement.

- *Policy Implementation challenges:* Existing agricultural policies lack consistent enforcement mechanisms, making it difficult to ensure compliance with CSA regulations.
- *Rigid and Centralised Policies:* Many policies related to farming and the environment are formulated at the national level without considering local variations. A one-size-fits-all approach limits the effectiveness of CSA strategies and evidence is required on local contexts and adaptability of generic offers.
- *Infrequent Policy Review:* Climate challenges are evolving, but farming policies and on-the-ground practice are not frequently updated to reflect emerging threats and opportunities. This limits the adaptability of policies to current realities.
- *Lack of Risk Mitigation Frameworks:* Farmers remain vulnerable to climate shocks and market fluctuations due to the absence of comprehensive risk mitigation policies.
- *Inadequate Engagement with Farmers and Experts*: Policymakers often struggle to involve farmers and CSA experts in decision-making, resulting in policies that lack effective grounding in different contexts.
- *Corruption and Mismanagement:* Corruption and misallocation of resources contributes to a lack of trust between farmers and policymakers.

2.4 Communication, Coordination, and Management Gaps

Examination of the current Climate-Smart Agriculture (CSA) initiatives that participants were aware of revealed gaps in communication, coordination, and management, hindering their potential impact.

- The fragmentation of CSA efforts across multiple institutions was felt by participants to create risk of inefficiencies and duplication of efforts, reducing the overall effectiveness of CSA programs.

- Many participants felt that there is poor communication between national, regional, and local CSA stakeholders. As a result, important information on CSA policies and best practices does not necessarily reach farmers.
- Government agencies, private sector actors and NGOs often work in isolation, for a variety of reasons, leading to a lack of synergy and duplication of CSA programmes and effort.
- Many CSA projects suffer from poor planning, inefficient resource use, and lack of accountability, reducing their long-term sustainability.

2.5 Socio-Cultural and Environmental Challenges

In addition to knowledge, resource, policy, and coordination challenges, several socio-cultural and environmental factors were identified, that further hinder CSA adoption in Nigeria and Ghana.

- *Resistance to CSA Adoption:* NGO staff and extension workers reported that farmers can be sceptical about adopting Climate-Smart Agriculture due to cultural beliefs, loyalty to ancestral crops and practices, local appropriateness of recommended seeds, fear of financial risks, and a lack of trust in government programmes. Another key reason for farmers' hesitation to adopt CSA is the reliance on the need to purchase improved seeds, rather than using their own seeds. This introduces several challenges; it creates a sense of dependency on external suppliers, imposes additional financial burdens on farmers, and raises concerns about seed availability and long-term sustainability, undermining farmers' sovereignty over their own agricultural practices.
- *Security Threats:* Many agricultural regions in Nigeria face security challenges such as armed banditry, and political instability. These issues disrupt farming activities and deter CSA investment.
- *Land Ownership and Tenure Issues:* Land ownership laws make it difficult for smallholder farmers to invest in long-term CSA projects. This is particularly challenging for female farmers, who face significant barriers to finances to support land ownership. In other cases, urban land acquisitions alienate rural farmers.
- *Gender Inequality:* Gender is a crucial factor in agriculture that must be approached with cultural awareness and sensitivity. In many rural communities, traditional norms continue to marginalise female farmers, particularly smallholders, who face systemic barriers to adopting climate-smart agricultural practices. This challenge was reported to be further compounded by the disproportionate impact of climate change on female farmers, who often have fewer resources and limited access to the support needed to adapt to environmental challenges. The challenges faced by female farmers are multifaceted and interconnected. Land tenure insecurity discourages long-term investment in sustainable farming, while cultural expectations often restrict women’s participation in agricultural leadership and market opportunities. Limited access to agricultural extension services, financial support, and mechanised farming tools further exacerbates their struggle.
- *Environmental Challenges:* Pollution from industries and improper waste disposal degrades soil health, affecting the productivity of CSA practices. Climate-related disasters, such as floods and droughts, further threaten CSA implementation

3. Opportunities for collaboration

The potential for transformation through cross-institutional collaboration across the UK, Nigeria, Ghana, and Brazil emerged as a strong theme in workshop discussions. However, the effectiveness of this collaboration and its translation into practice depends on the engagement of industry in all countries, robust government support for partnership development, necessary R&D to close knowledge gaps, and the involvement of local NGOs. Data from the workshop and interviews highlighted a strong desire among stakeholders for more effective use of technology, particularly in providing a platform for knowledge sharing and real-time data on soil health and weather forecasts. A key consideration in terms of technology is ensuring its accessibility to farmers, both in terms of cost and language.

The diverse mix of sectors represented from across Nigeria, Ghana, Brazil, and the UK included academic institutions, private technology developers, and government agencies, with a focus on specialisations such as innovative agricultural technologies, soil health monitoring, and digital agriculture solutions as well as more traditional farm advisory offers. Notable potential opportunities for collaboration emerged, including technology developers providing digital platforms for farmer information delivery; academic institutions with research expertise in soil and water assessment and farmer engagement; and agri-sector advisory entities offering specialised environmental knowledge and technology transfer opportunities.

CSA implementation requires a multi-faceted, collaborative approach both in R&D to evidence pathways, and demonstration and trials to evidence benefits across sectors. Key opportunities for collaboration that emerged include:

1. Addressing knowledge gaps, where many farmers lack understanding of CSA principles and soil health management. This necessitates collaborative development of training programmes and knowledge-sharing platforms with careful attention to fusing traditional knowledge within communities, with external input tailored/tailorable to local contexts.
2. Collaboratively adapting expertise in precision farming technologies and soil monitoring to the specific contexts of Nigeria and Ghana, to overcome technology gaps identified by stakeholders. In parallel, integrating indigenous farming knowledge, essential for culturally relevant solutions, with modern scientific practices requires partnership with local NGOs and communities.
3. Policy development that benefits from collaborative R&D input, allowing for the creation of inclusive and adaptable frameworks that address weak policy enforcement and rigid, centralised approaches.
4. Information gathered also highlighted the importance of collaborative financial models, such as addressing limited access to credit and high technology costs, and market access strategies, fostering economic empowerment for smallholder farmers who face significant financial constraints. There is a key opportunity for green finance models, but this needs further exploration.

5. Socio-cultural barriers such as gender inequality and resistance to new practices require cross-sectoral collaborative solutions that respect local norms while promoting equitable access to resources and knowledge (as described in detail above and below).

4. Key stakeholders and their roles

Successful collaborative projects within this topic area necessitate the engagement of a diverse range of stakeholders across each participating country. Key stakeholders identified included:

Government agencies *in Nigeria and Ghana*: Our evidence from stakeholders emphasises that these agencies play a crucial role in policy development, regulatory frameworks, and resource allocation, creating an enabling environment for innovation and adoption. However, bottom-up change requires on-the-ground evidence bases that farmers trust and these must be developed through participatory action and training in new technology that serves both top-down and bottom-up transformation needs. UK and Brazilian overseas-focused government agencies remain important to support knowledge exchange and partnership development in-country, but programmes need to build in mechanisms to embed sustainable transitions.

Academic and research institutions *(Nigeria, Ghana, UK and Brazil)***:** These need to be enabled to provide the fundamental research, knowledge, and expertise necessary for developing leading-edge technologies and practices wherein co-development of programmes and evidence bases with communities is essential to ensure relevance and adoptability.

Non-governmental organizations (NGOs) and community-based organizations *(Nigeria, Ghana, UK and Brazil):* Traditionally bridging the gap between research and practical implementation, ensuring that solutions are context-appropriate and reach end-users, particularly smallholder farmers. These are crucial partners to support scaling and underpinning relevance and there was strong support for NGO involvement in future programmes.

Industry and commercial entities *(there was more engagement in this sector from UK and Brazil but scope for knowledge transfer to Ghana and Nigeria should be explored as a priority*): **O**ur engagements revealed clear potential for agri-technology innovation. There is a strong appetite in the sector for commercialising technologies and establishing sustainable market linkages. Community advocacy and expert trials are required to ensure accessibility and relevance, and to build trust. Agri-tech developer collaboration in research and trials is essential to ensure development and deployment translates into viable products and services, fostering economic development from the small-holder perspective as well as scaling up successful interventions.

Farmer associations and cooperatives *(Nigeria and Ghana and also Brazil where similar agroclimatic parallels and challenges were identified)*: Vital partners (alongside NGOs) for providing feedback, facilitating trials and adoption, and ensuring that solutions meet the real-world needs of agricultural communities.

5. Gender and social inequality

Women play an important role in the agricultural sector across Ghana and Nigeria. It was cited by a stakeholder, for example, that in northern Ghana, women make up approximately 48% of the workforce and contribute significantly to food production and household sustenance.

Stakeholder testimonials revealed that cultural norms around gender roles in agriculture vary across different regions of Ghana and Nigeria. In many areas, gender equality is actively promoted, with women having equal rights and access to the same resources as men. However, in some rural communities, women still face significant barriers that hinder their ability to adopt climate-smart agriculture. These challenges are particularly pronounced for female smallholders, who are often marginalised and vulnerable, with limited access to education and economic resources.

The challenges faced by women farmers in Ghana and Nigeria reflect a broader global reality, where 40% of the agricultural workforce in developing countries comprises women, yet their productivity lags 20–30% behind men due to systemic inequities. This gap persists despite women's contributions to 80% of global food production through smallholder and family farming systems forming the backbone of agriculture and food security worldwide. Frameworks like the UN Decade of Family Farming (2019–2028) emphasise the significance of gender equity in achieving food security, with Climate-Smart Agriculture (CSA) emerging as a critical approach to match productivity, adaptation, and emissions reduction.

Initiatives like Nigeria's Investing in Women in Nigeria (IIW-Nigeria) programme, funded by Global Affairs Canada to increase incomes, improve climate resilience and transform their livelihoods. The target value chains include maize, rice, soya bean, groundnut, and poultry. Ghana's Agriculture for Food and Jobs (AAFORD) project integrates gender equality into capacity-building for smallholder farmers, prioritising vulnerable women and youth through collaborations with Village Savings and Loans Associations (VSLAs) and farmer cooperatives. These examples show how policy innovations can enhance women's access to resources and markets. Nigeria's Federal Ministry of Agriculture and Rural Development (FMARD) has institutionalised the National Gender Policy in Agriculture for gender audits and gender-disaggregated data collection, to track disparities in input distribution and mechanisation access. Ghana's Ministry of Food and Agriculture (MoFA) mandates that 40% of extension service beneficiaries be women, complemented by the Women in Agricultural Development (WIAD) directorate's focus on workload-reducing technologies.

Nigeria and Ghana both prioritise gender-responsive budgeting, with Nigeria allocating funds to value chains where women dominate, such as cassava and groundnuts, to rectify historical underinvestment. The following points outline the specific challenges faced by female farmers in relation to climate smart agriculture.

- *Land Ownership and Tenure Security:* Participants reported that in many rural areas, land ownership is predominantly controlled by men, with women often relying on family or leased land. While efforts have been made to promote gender-inclusive policies in agriculture and land ownership, challenges remain in terms of implementation and enforcement at the local level. In some areas, policies that support women's rights or provide funding for female farmers lack transparency of use, are not fully implemented, or women may be unaware of

them or how to access the support they offer. To promote gender equity in land ownership, it is crucial to implement gender-sensitive land tenure policies that enable women to have equal access to, and ownership of, land. Providing legal assistance and awareness-raising programmes can empower women to better understand what is available to them. Developing community-based land allocation models that integrate women's ownership rights within customary land tenure systems will help bridge the gap between legal frameworks and traditional practices, creating more inclusive and sustainable land governance.

- *Cultural Norms and Gender Roles in Agriculture:* Traditionally, decision-making on land management, and crop choice, has been in the hands of the male head of the family. Many women are now actively contributing to sustainable agricultural practices, with a growing awareness of the importance of gender inclusivity in farming gradually challenging these entrenched norms. To foster gender-inclusive agricultural practices, it is essential to engage local leaders and male allies as advocates for change. Their support can help shift societal attitudes and create a more enabling environment for women's full participation in CSA agriculture. Supporting women's involvement in agricultural cooperatives and leadership roles is another critical step in strengthening their decision-making power. By supporting cultural change to enable women to have a voice in agricultural governance, communities can benefit from more inclusive and equitable food systems. Designing community-based training programmes for both men and women that include gender awareness, can play a crucial role in challenging restrictive cultural norms and promoting greater gender equity in farming.

- *Access to Agricultural Extension Services and Training:* Agricultural extension services are vital for providing training and information on climate-smart practices, yet female farmers often face challenges in accessing these services. The lack of female extension officers and the limited availability of services tailored to women can hinder their ability to adopt new techniques. Women may also face barriers such as time constraints due to domestic responsibilities, or transport limitations, making it difficult for them to participate in training sessions. This lack of access to professional guidance and information contributes to a reliance on informal knowledge-sharing, which may not always be up to date, accurate or contextually appropriate. To enhance support for women in agriculture, recruiting and training more female agricultural extension officers is essential. Their presence can improve outreach to women farmers, ensuring they receive the guidance and resources needed to succeed. Developing flexible and locally accessible training formats is equally important. Mobile outreach and community-based learning hubs can help overcome barriers such as time constraints and transport challenges, making agricultural education more inclusive and practical. Integrating indigenous knowledge into CSA training ensures that learning remains culturally relevant and grounded in local traditions. By valuing and incorporating traditional practices, training programmes can better resonate with communities and promote sustainable, context-specific agricultural solutions.

- *Financial Access and Investment in Climate-Smart Practices:* Access to finance remains a significant barrier for female farmers in rural areas. Many women struggle to access loans or

credit because they do not own land or have other forms of collateral required by formal financial institutions. Even when they do secure financial support, women may face challenges in managing these resources effectively, often due to a lack of control over household finances or external factors such as appropriation of funds by family members. Limited access to affordable agricultural inputs, such as seeds, fertilizers, and tools, further hampers the ability of female farmers to implement climate-smart farming techniques. Supporting women's participation in farmer cooperatives can support them to secure better prices, access shared resources, and enhance their economic resilience.

- *Labour and Mechanisation in Climate-Smart Agriculture:* Climate smart agriculture often requires labour-intensive methods, such as composting, mulching, and water harvesting. These practices can be physically demanding and women, who are frequently responsible for multiple domestic and farming tasks, may face challenges in managing the additional workload. The lack of access to mechanised farming tools designed for women, or the high cost of such tools, further limits the adoption of more efficient, climate-resilient farming techniques. Women's role in labour-intensive activities can also be undermined by insufficient decision-making power or the inability to mobilise help from other family members. Developing and subsidising climate-smart mechanised tools designed for women, such as lightweight ploughs and efficient irrigation systems, can significantly enhance their productivity and ease the physical burden of farming. Ensuring that these tools are accessible and tailored to women's needs is crucial for promoting inclusive agricultural development. Facilitating cooperative ownership of mechanised equipment can further reduce costs while increasing social cohesion, allowing women farmers to share resources and benefit from advanced technologies without the financial strain of individual ownership.
- *Technology, Digital Literacy, and Climate Information:* While technological tools hold significant potential for advancing climate-smart agriculture, female farmers often face limited access to these resources. Although internet access and mobile phone usage is improving, access to smartphones and digital farming tools remains uneven, with many women unable to afford the devices needed to engage with digital agriculture platforms. In some rural areas, technology is perceived as a male field, and women often lack the confidence to approach it. Providing digital literacy training together with training on the use and maintenance of climate smart agriculture technologies is essential to empower women to fully participate in digital agriculture. Equipping women with the necessary skills and knowledge will enable them to maximise the benefits of modern tools, increase yields, and build climate resilience in their farming practices.

- *Indigenous Knowledge and Innovation:* Female farmers possess a wealth of traditional agricultural knowledge, which has often formed the foundation for past sustainable farming practices. Indigenous knowledge enables farmers to adapt to changing environmental conditions and improve soil fertility through methods like composting and the use of organic materials. However, women often lack the necessary support to scale up these traditional practices or to integrate modern techniques that could further enhance their effectiveness. There is significant potential for greater collaboration between research institutions and female farmers to refine and share these innovative practices, enabling them to better

address climate challenges. Providing entrepreneurship opportunities for female farmers, particularly in producing effective organic products, could encourage more women to enter the field while empowering them.

6. Barriers to transformational change

The successful and sustained implementation of CSA depends on farmers' ability and willingness to adopt and integrate these practices. However, deeply rooted cultural norms, limited knowledge, inadequate support, and scarce resources often hinder adaptation. Overcoming these challenges requires a comprehensive approach that builds farmers' capacity, provides incentives, and ensures access to necessary resources. Achieving these demands requires strong cross-sector collaboration among governments, academia, local and international NGOs, and industry. This section explores the key barriers to transformation across these sectors, as well as the cultural factors that hinder adoption within rural farming communities.

At the **state level**, there are perceptions of inefficiency, mismanagement, and fragmented approaches that can pose significant challenges to CSA adoption in Nigeria. The misallocation of resources and lack of transparency weaken both national and international initiatives, while poor coordination means that many CSA strategies operate in isolation, disconnected from broader agricultural investments. Policies often fail to integrate local knowledge or adapt to regional variations in climate, soil conditions, and farming practices, further hindering transformational change.

Weak communication and poor coordination exacerbate these issues where present. Participants noted that limited collaboration between government agencies, NGOs, private sector actors, and farmers leads to duplicated efforts and inefficient resource use. Policies are frequently developed without meaningful engagement with the farmers and practitioners who implement them, resulting in impractical solutions. Without stronger interdisciplinary cooperation and more streamlined governance, the scalability and long-term impact of CSA remain constrained.

At the grassroots level, **local NGOs** and community initiatives reported significant progress using systemic and holistic approaches that effectively engage farmers and local authorities. However, despite their direct impact on rural communities, these initiatives are often excluded from major policy-making processes, limiting their influence on broader agricultural and climate strategies. Furthermore, a key barrier to scaling these efforts is the persistent lack of resources to trigger change that can become self-sustaining.

Although knowledge-sharing between **academic and research institutions** in Nigeria, Ghana, and the global community is well established, translating this knowledge into practice remains a challenge. Whether due to its failure to inform policymaking or the lack of accessibility for farmers, a disconnect persists between research and implementation. Both countries possess rich indigenous knowledge, particularly in soil health, which often aligns with agroecological

principles. However, failure to integrate this knowledge with modern CSA techniques limits farmers' willingness to adopt new practices.

Another major challenge is the lack of trust between farmers and the **industries** that supply resources and technologies. As an example, farmers are often encouraged to purchase higher-quality seeds instead of using their own cultivated varieties - without a clear pathway to becoming seed producers themselves. This fosters dependency on external suppliers and diminishes trust in the system. Addressing this issue requires a focus on knowledge-sharing, trust-building, and clear demonstrations of the locally specific benefits of recommended techniques and inputs to ensure long-term adoption.

Cultural norms play a critical role in shaping agricultural practices. Loyalty to ancestral traditions and crop choices can present a significant obstacle to the adoption of CSA techniques. The perceived dissonance between modern CSA approaches and indigenous knowledge further discourages farmers from taking the risk of modifying their farming practices. Bridging this gap requires strategies that integrate traditional wisdom with climate-smart innovations, ensuring that new practices align with local values and experiences. Demonstration plots showcasing the effectiveness of integrating CSA techniques, along with risk mitigation support for farmers, can help build confidence and encourage adoption.

Gender inequality in some rural communities across Nigeria and Ghana presents a significant barrier to transformative change in agriculture. Women play a crucial role in farming in both countries and are highly engaged in training for sustainable agriculture. However, systemic challenges, as outlined above, prevent them from taking a more central role in the transformation process.

In many rural regions of Nigeria and Ghana, men have traditionally held land ownership rights, while women primarily serve as labourers. Influenced by education and exposure to Western culture, many male heads of the family allocate plots to their spouses. In some cases, these lands are remote, degraded, and less fertile. It was reported that women typically work on their husbands' land while maintaining their own smaller plots for household sustenance. Their limited access to mechanised tools and chemical fertilisers makes them more inclined to adopt agroecological methods such as organic fertilisation and rotational cropping to diversify household food production. However, scaling up these sustainable practices requires improved access to resources, labour, appropriate tools, and knowledge-sharing opportunities. Addressing these challenges is essential to ensuring that women are not only participants but also leaders in the transition to climate smart agriculture.

Opportunities for transformational change framed around the three InnovateUK priority drivers:
Innovation: Innovations are needed in several areas including the development of innovative solutions that address critical areas such as context-specific knowledge, the integration of indigenous practices, and affordable technology. Improving soil health and productivity requires research and knowledge of the crop-specific and agroecological zone to identify the challenges

and opportunities associated with specific regions and develop tailored strategies for optimising crop yields while minimising environmental impacts. Innovative approaches should integrate indigenous agricultural practices with modern CSA techniques and solutions to reduce resistance and increase the adoption of sustainable farming practices. This integration not only preserves cultural heritage but also fosters a sense of ownership among local communities. The cost of modern agricultural technology is high especially for rural farmers, limiting adoption at the community level. There is a pressing need to develop affordable and accessible agricultural technology including digital tools for knowledge sharing and real-time data collection, enabling farmers to make informed decisions and respond effectively to changing conditions.

Evidence of effectiveness: Central to discussion of both bottom-up and top-down catalysts for CSA adoption at scale is robust evidence to support both small-holder farmers agri-business decision making through to policy development that is relevant and implementable. A critical component of this evidence base lies in the development and deployment of accessible soil and crop assessment technologies. Traditional soil testing methods are often costly and time-consuming, hindering the ability of farmers and policymakers to make informed decisions about soil health management. By leveraging innovative technologies, such as portable sensors, remote sensing, and AI-driven data analysis, it will be possible to generate real-time, localised data on soil health indicators. This data not only empowers farmers to adopt targeted CSA practices and see for themselves potential benefits but also provides policymakers with the necessary evidence to design effective interventions and track their impact. Demonstrating the effectiveness of these relevant agri technologies through rigorous field trials and pilot projects is essential for building trust and driving widespread adoption of CSA practices.

Capacity and Capability: Human resource and capacity issues were raised, with limited awareness of CSA among policymakers, weak advocacy, and outdated policies that hinder transformational change. National policies often fail to reflect local realities and are not updated regularly to address new challenges and opportunities. With regard to resource limitations, challenges include insecure land tenure, high cost of technology, inadequate infrastructure, and insufficient financial resources. Insecure land tenure discourages long-term investments in CSA practices, particularly for women farmers who face significant barriers to land ownership.

7. Summary and future vision

We adopted a multi-faceted approach to gather insights from a wide range of sectors to develop a deeper understanding of the challenges and needs to support soil health for productivity and climate resilience. The process drew upon participatory workshop activities followed up with a series of in-depth interviews and meetings conducted with key stakeholders, including agri-consultants, NGOs working with farmers in Nigeria and Ghana, and experts from academic and technological sectors. The pivotal workshop convened in Abuja, brought together over 40 participants from 25 organisations spanning Nigeria, Ghana, and the UK. This workshop served as a framework for collaborative dialogue and knowledge exchange especially with experts in Brazil, further enriching our understanding of the challenges and collaborative opportunities in CSA. Targeted stakeholder consultations were conducted in Brazil and the UK to identify potential industrial and research collaborators.

The findings of this scoping exercise have demonstrated the critical need for targeted R&D investment to drive transformational change in CSA within Nigeria and Ghana. We have identified key areas where collaborative innovation between UK, Brazil, Ghana, and Nigeria can yield significant advancements. Focal areas for this theme include soil health assessment, digital agriculture, and participatory co-development of training and peer-to-peer exchange for expanding climate-resilient practice (land and crop management), all of which can accelerate the development and deployment of context-appropriate technologies and practices, empowering farmers and building resilient agricultural systems**.**

Appendix: Links to media coverage of project activities

Links to Media Coverage

1. "FG Committed To Advancing Climate-Smart Agriculture Research -Utsev" https://thefact.ng/fg-committed-to-advancing-climate-smart-agriculture-research-utsev/
2. "FG to Set up Coalition to Advance Climate-Smart Agriculture Research" https://distinctnews.com.ng/fg-to-set-up-coalition-to-advance-climate-smart-agriculture-research/
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