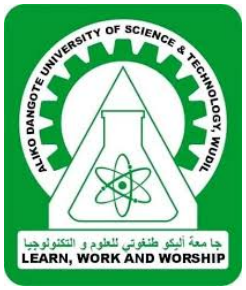

IFPRI Discussion Paper 02380

November 2025

Bridging the Gap

How Human-Centered Design Can Help Unlock Bottlenecks in the Diffusion of Small-Scale Irrigation in Nigeria

Bedru Balana
Aminu Abba
Augustine Iraoya
Musa Tukur Yakasai
Bello Yakasai
Kabiru Abdullahi
Ahmed Usman Shuaibu
Nuruddeen Muhammad Musa
Oliver Kiptoo Kirui
Hyacinth Edeh
Claudia Ringler

Natural Resources and Resilience Unit
Development Strategies and Governance Unit

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

The International Food Policy Research Institute (IFPRI), a CGIAR Research Center established in 1975, provides research-based policy solutions to sustainably reduce poverty and end hunger and malnutrition. IFPRI's strategic research aims to foster a climate-resilient and sustainable food supply; promote healthy diets and nutrition for all; build inclusive and efficient markets, trade systems, and food industries; transform agricultural and rural economies; and strengthen institutions and governance. Gender is integrated in all the Institute's work. Partnerships, communications, capacity strengthening, and data and knowledge management are essential components to translate IFPRI's research from action to impact. The Institute's regional and country programs play a critical role in responding to demand for food policy research and in delivering holistic support for country-led development. IFPRI collaborates with partners around the world.

AUTHORS

Bedru Balana (B.balana@cgiar.org) is a Research Fellow in the Natural Resources and Resilience (NRR) Unit of the International Food Policy Research Institute (IFPRI), Washington, DC.

Aminu Abba (aabba.ext@buk.edu.ng) is a Professor at Bayero University Kano, Nigeria.

Augustine Iraoya (a.iraoya@cgiar.org) is Research Analyst in IFPRI's Development Strategy and Governance (DSG) Unit, Abuja, Nigeria.

Musa Tukur Yakasai (musatukur28@gmail.com) is Vice-Chancellor of Aliko Dangote University of Science and Technology (ADUST), Wudil, Kano, Nigeria.

Bello Yakasai (belabsy2@gmail.com) is a Visiting Fellow at ADUST, Wudil, Kano, Nigeria.

Kabiru Abdullahi (kbyabdu@gmail.com) is a Senior Lecturer at ADUST, Wudil, Kano, Nigeria.

Ahmad Usman Shuaibu (ahmadmarmara@yahoo.com) is a Professor at ADUST, Wudil, Kano, Nigeria.

Nuruddeen Muhammad Musa (mnuruddeen@gmail.com) is a Professor at ADUST, Wudil, Kano, Nigeria.

Oliver Kiptoo Kirui (o.k.kirui@cgiar.org) is Acting Program Leader for Nigeria and a Research Fellow in IFPRI's DSG Unit, Abuja, Nigeria.

Hyacinth Edeh (h.edeh@cgiar.org) is Country Program Manager with IFPRI's DSG Unit, Abuja, Nigeria.

Claudia Ringler (c.ringler@cgiar.org) is Director of IFPRI's NRR Unit, Washington, DC.

Notices

Abstract

Ample evidence shows that small-scale irrigation (SSI) has positive impacts on agricultural productivity, poverty reduction, climate resilience and household food security, nutrition. Despite this, adoption of SSI has remained low in sub-Saharan Africa, including Nigeria, where previous research suggests potential for adoption is largest. Factors such as high cost of technologies, farmers' risk behavior, lack of incentives, and lack of access to finance and capacity gaps have often been noted as key constraints limiting the adoption/scaling of SSI among smallholders. However, in an environment with low overall levels of use, it is important to not only focus on the challenges experienced by smallholder farmers, but also on those of key intermediary actors—specifically government, irrigation equipment distributors, and finance institutions—that are critical for a supportive enabling environment of SSI technology diffusion. To understand the constraints these groups encounter and propose innovative policy, financial, and supply chain solutions, we conducted a series of human-centered design (HCD) workshops in three locations in Nigeria. Key solutions proposed during nine workshops include the need for cross-sector coordination and policy harmonization, improved data and digital systems and platforms, customized financial products and risk-sharing options for SSI, capacity-sharing for extension services, and specific strategies to support women farmers so that they benefit equally.

Keywords: Small-scale irrigation, government, financial institutions, irrigation equipment dealers, human-centered design, Nigeria

Acknowledgments

This work was under the umbrella of the CGIAR Science Program on Policy Innovations. We would like to thank the Gates Foundation for supporting this work.

Contents

1. Introduction

Irrigation, and particularly small-scale irrigation (SSI), has positive impacts on agricultural productivity and poverty reduction in sub-Saharan Africa (Woodhouse et al., 2017; Xie et al., 2018; Wiggins and Lankford, 2019). The technology has, furthermore, proven to support climate resilience, generate employment, reduce seasonal shortfalls in food supply, improve nutrition and reduce the region's food import dependency (Burney and Naylor, 2012; Mekonnen et al., 2022; Passarelli et al., 2018; Balana et al., 2020; Xie et al., 2018). The growing number and intensity of extreme climatic events, in particular droughts, results in significant adverse impacts on agricultural production and livelihoods, particularly affecting marginalized farming populations, including women farmers in sub-Saharan Africa, where agricultural production is predominantly rainfed. Studies show that despite its high potential for irrigated farming, the share of irrigated area among all cultivated areas in Nigeria is as low as one percent, which is less than one-tenth of the irrigation potential in the country (You et al., 2011). According to Xie et al. (2017), the potential for expanding SSI in Nigeria sustainably is about one million hectares for dry season farming and 0.65 million hectares in the rainy season. FAO AQUASTAT estimates show that the actual irrigated area in Nigeria is only about 0.2 million ha (excluding the Fadama[1] area of about 0.7 million ha).

Among all countries in sub-Saharan Africa, Nigeria has the largest potential for the expansion of SSI (You et al., 2011; Xie et al., 2014) but adoption has remained limited. A recent review (Durga et al., 2024) identified, in addition to high cost, uncovered risks, lack of incentives, and lack of capacity as the key factors limiting the adoption of solar-powered irrigation as well as limited market development and geographical constraints. Many of these constraints also apply to other SSI technologies. The authors suggest a systems approach and the design of *context-specific solutions* to address risks, incentives and capacity challenges.

The government, irrigation equipment distributors, and financing institutions are critical intermediary groups for accelerating the scaling of SSI, but each of these groups lacks critical information to scale context-specific irrigation solutions. A survey with solar pump distributors that IFPRI implemented in 2021 in central and northern Nigeria identified, among others, lack of farmer information, high cost and lack of financing as the key constraint to scaling of this SSI technology, while a workshop with government actors identified a need for a more conducive enabling environment for SSI. This calls for a structured process to understand and address the constraints of these intermediary actors in the scaling of SSI process.

[1] The term 'Fadama' is a Hausa name for irrigable land. With the support for the World Bank, the Fadama-I project was started as a pilot agricultural project in 1992 and was then scaled up as Fadama-II and Fadama-III covering the country as a whole until the Fadama series of projects ended in 2019. The Fadama project became a community-driven development model and a national brand of local agricultural development (https://blogs.worldbank.org/nasikiliza/delivering-development-collaboration-key-success-nigerias-fadama-projects).

In short, despite its immense potential in Nigeria, the uptake and scaling of SSI technologies have been constrained by a range of systemic challenges—from policy and institutional bottlenecks to financial and technical barriers (Ogunjimi and Adekalu, 2002; Xie et al., 2017; Takeshima, 2016).

Irrigation operates not in a vacuum but is part and parcel of a broader socio-ecological system (Lam, 2006; Fernald et al., 2015; da-Silva-Branco et al., 2026). This socio-ecological system includes actor groups that affect the operating space of farmers who would like to access and use SSI. Understanding this space is particularly important in environments with low overall levels of technology use. In such socioecological systems, the role of intermediary actors that define the enabling environment for SSI operating spaces play a particularly decisive role. Key intermediary actors for SSI include the federal and state governments given the need for a supportive policy environment; the finance system given the considerable cost of SSI technologies; and irrigation equipment suppliers, without whom such technologies could not be accessed. As gender-blind technology support can increase the gaps in assets, achievements and empowerment between women and men farmers (Theis et al., 2018) it is also important to understand how actions or lack of actions by intermediary actors in the SSI environment affect women and men farmers differentially and what measures could be taken to ensure that women farmers also (and ideally equally) benefit from SSI technologies.

The reminder of this paper describes the key intermediary actors, describes the methodology used to identify challenges and solutions proposed by these actors, and synthesizes key results. It concludes with practical suggestions to strengthen the diffusion of SSI through providing intermediary actors with better data, tools and through strengthening coordination across actor groups.

2. Overview of the three Intermediary actors

2.1 Government

The National Agricultural Transformation and Innovation Policy (NATIP 2022–2028) describes agriculture as a critical sector for fostering sustainable and inclusive economic growth, food security, rural incomes, and employment in Nigeria (FMARD, 2022). It recognizes that growth in agriculture has the greatest impact on poverty reduction and food security. However, the sector is characterized by low productivity as highlighted in the two recent agricultural policy documents preceding the NATIP—the Agricultural Transformation Agenda (ATA) (2010/11–2016) and the Agricultural Promotion Policy (APP) (2016–2020) (FMARD, 2016). This is mainly due to low adoption of productivity-enhancing technologies such as irrigation, fertilizer, and improved seeds.

Irrigation, and particularly SSI in Nigeria sits "between two chairs", that is, those held by the Federal Ministry of Agriculture and Food Security and the Federal Ministry of Water Resources and Sanitation. In response to severe food inflation and higher energy prices, the Federal Ministry of Agriculture and Food Security has started to consider supporting the expansion of small-scale

solar irrigation technologies. Early engagement with these two key national actors suggests that there is a lack of decision support to guide the government's irrigation development interventions, particularly on appropriate '*crop type-irrigation technology*' combinations.

2.2 Irrigation equipment suppliers/distributors

Like in other low- and middle-income countries, agricultural input markets, in general, and markets for irrigation equipment, in particular, in Nigeria are either missing or characterized by a high degree of imperfection. The supply chain for irrigation equipment comprises manufacturers, importers/wholesalers, and retailers. The industry is mostly composed of overseas manufacturers, few importers and distributors, and a relatively larger number of retailers concentrated in major cities. Thus, despite the high potential of farmer-led SSI, its expansion is limited by supply side factors.

Demand side factors also matter. Firstly, most smallholder farmers cannot afford the upfront investment cost of purchasing irrigation equipment such as pumps and irrigation kits. Secondly and concomitantly, innovative leasing and financing schemes that could allow more farmers to hire or purchase irrigation equipment are not available. Thirdly, smallholders struggle to meet the high cost of energy by using pumps for water lifting (de Fraiture and Giordano, 2014). Fourthly, farmers lack information and access to appropriate complementary agricultural inputs such as improved seeds and agrochemicals. This also limits small farmers' ability to reliably produce crops of good quality and improve on-farm incomes.

Some of these challenges are directly or indirectly linked to either lack of or limited involvement of market-oriented private actors in irrigation supply chains. The manifestations of the problem include limited or a complete lack of market-oriented private provision of irrigation services, equipment supply, innovate financing products, and technical and advisory services in the SSI supply chains. Yet, studies on the supply side show that 'irrigation service provision' is economically feasible and a promising business opportunity, while on the demand side irrigation services to farmers remain unfulfilled (Tesfaye, Balana & Bizimana, 2021). According to de Fraiture and Clayton (2012) "*farmers who own or use rented pumps cultivate more land, get higher yields and earn twice as much as farmers who water by hand and farmers are generally aware of this*". For farmers who cannot afford to own a pump, pump rental or paying for the services of a private irrigation services provider are two possible options. However, in practice, the actual involvement of market-oriented private actors in irrigation supply chains in Nigeria is very limited.

2.3 Financial institutions

Poor access to financial services to smallholder farmers has been identified as one of the key constraints limiting adoption of agricultural technologies including irrigation in Nigeria (FMARD, 2016). Beyond smallholder farmers, limited access to financial services also adversely affects input suppliers, crop processors and traders, and other private sector firms engaged in agribusiness value chains. According to the Agricultural Promotion Policy (2016–2020), insufficient access to

credit and insurance products, high interest rates, and non-recognition of cooperatives and farmer-based organizations by financial institutions are among the major constraints to agricultural financing in Nigeria. Furthermore, informal sources (especially borrowings from family and friends) dominate rural credit in Nigeria as only two percent of rural dwellers have accessed credit from formal financial institutions. In terms of savings, nationally representative data collected by the Enhancing Financial Innovation and Access (EFInA) show that only about 56 percent of rural dwellers reported some savings, but most of these savings are held through informal or traditional means (EFInA, 2020).

To mitigate the problem of agricultural financing, several policy interventions, such as the Nigerian Incentive-based Risk Sharing System for Agricultural Lending (NIRSAL) (2011); the Growth Enhancement Support Scheme (GES) (2012), and the Anchor Borrowers' Program (ABP) (2015), were instituted by the government of Nigeria. Yet, access to agricultural finance remains a major challenge for smallholder farmers and others involved in the agri-food value chains in Nigeria (World Bank, 2022). Lending organizations are largely constrained by the unique risks in the sector, high transaction costs often associated with dealing with large number of smallholder farmers, and micro, small, and medium enterprises (MSMEs) that dominate the agri-food value chains. Out of the 38 million financially excluded adults in Nigeria, 81 percent are from rural areas (EFInA, 2020). On the other hand, there is limited effective demand for finance by agri-food value chain actors because of their inability to meet the often-demanding requirements such as inadequate collateral and risk-averse behavior of smallholders (Balana et al., 2022).

The financial gap (both credit and savings) among rural smallholders on the one hand and the availability of the network of financial service agents on the other, presents a market opportunity for designing, promoting, and scaling appropriate financial services to agri-food value chain actors. To better understand the availability and accessibility of financial services and examine the viability of financing for smallholder irrigation technologies, we will map the supply side (financial institutions) and demand side (irrigated producers) factors using selected indicators such as distance to bank branch and/or mobile money agent, mobile connectivity, and distance to all-weather road.

3. Methods

To understand constraints of intermediary actors in the SSI environment, a series of human-centered design (HCD) workshops were conducted in three Nigerian regions: Kano in the Northwest, Oyo in the Southwest, and the capital region of Abuja; reflecting different agroecological environments, different levels of SSI adoption and including the national government. Each workshop gathered government officials, financial service providers, and irrigation technology suppliers (with the exception of Abuja, where only government and financial intermediaries were consulted) to capture their perspectives on SSI and collaboratively design solutions. Invitees were drawn from a comprehensive database of all government actors, financial

institutions and irrigation technology vendors in the three regions. The HCD events were held in Kano State (Feb. 19–20, 2025), Oyo State (Apr. 7–10, 2025), and Abuja (Jun. 24–25, 2025). Numbers of participants by region and intermediary actors are shown in Table 1.

Human-Centered Design is an approach to problem-solving that places the needs, experiences, and perspectives of users at the center of the design process. It is sometimes called user-centered design or even people-centered design (Brown & Wyatt, 2010; IDEO, 2016). It aims to co-create solutions that are intuitive, effective, and impactful by deeply understanding the context and goals of the end users. Unlike traditional design processes that may be driven by technology, HCD ensures that human experiences and insights guide every stage of development.

The HCD approach used in the workshops involved three phases: *Empathy, Define*, and *Ideation*. This sequence allowed participants to first express their experiences and pain points, then distil these into core problem statements, and finally brainstorm potential solutions. Other research had used multi-stakeholder dialogues to drive transformative change in the smallholder irrigation sector (Minh et al. 2020). As the goal here was to first identify actor group specific challenges, HCD meetings were held separately with each stakeholder group.

By engaging diverse stakeholders in this co-creation process, the workshops uncovered bottlenecks limiting the effectiveness and scalability of SSI and generated a rich set of ideas to address them. Crucially, these insights provide guidance on how to design and implement tools for supporting and guiding policy, investment, business/marketing and lending decisions along the SSI supply chain to support accelerated, inclusive and sustainable SSI development. Each workshop lasted between 2 and 3 hours. A set of pre-determined questions[2] relevant to each group, developed by the research team before each workshop, were used to guide the HCD workshops.

Table 1. Number of HCD workshops and participants (by intermediary groups and geographies)

Intermediary Groups	States (Geographies)			Total
	Kano (# participants)	Oyo (# participants)	Abuja (FCT) (# participants)	
Government	10	11	13	34
Financial Institutions	14	12	9	35
Irrigation equipment Suppliers	11	5	-	16
Toal	35	28	22	85

[2] The HCD guiding questions are presented in Annex 1.

The HCD events consider three core principles: *Empathy, Collaboration* and *Iteration*.

- **Empathy** relates to a deep understanding of intermediary actor needs. Developing a deep understanding of the needs, aspirations, and pain points of intermediary actors is the cornerstone of HCD. For example, government agencies might face challenges related to data accessibility for decision-making, while irrigation equipment distributors may need better tools to assess market demand. Techniques such as interviews, focus group discussions, and surveys can uncover these nuanced insights.
- **Collaboration** focuses on engaging diverse stakeholders. Engaging diverse stakeholders fosters innovation and inclusivity. For instance, a collaborative workshop involving government representatives, distributors, and financial institutions can reveal overlapping concerns and synergies. By bringing stakeholders together, solutions can address interlinked challenges, such as financing mechanisms for SSI
- **Iteration** includes prototyping and testing ideas for continuous improvement to ensure the solutions are refined based on feedback. Iterative cycles reduce the risk of developing impractical or irrelevant solutions. For example, a prototype of irrigation equipment might be tested with distributors and adjusted based on their input about *desirability (human), viability (business)*, and *feasibility* of the technology (Munger & Van, 2020).

The HCD process consists of five phases iterative activities – *Empathy, define, ideate, prototype and pilot testing* phases. The *empathy phase* captures stakeholder experiences, emotions, and aspirations through empathy maps. The *define phase* translated these experiences into problem statements. The *ideation phase* facilitates brainstorming to co-develop practical solutions to the problems identified at the define phase. A *prototype* is a simplified version of a product that allows you to test ideas and designs before committing time and money to full development. Thus, the *prototype* phase allows designers to determine whether or not the design works the way it's intended before it is out in the world and in the hands of users. The *pilot testing* allows deployment of prototypes in real-world scenarios. For instance, test a financing institution's use of a gender-responsive loan calculator in assessing SSI project proposals. The HCD findings presented in this paper refer to the first three phases (i.e*., empathy, define, and ideate)* of the workshops.

4. Key Findings from the HCD

4.1 Government Stakeholders

Government representatives participating in the HCD events in the three locations included officials from agricultural agencies, water resources, and planning commissions, among others. They identified a number of institutional and policy-related challenges that hinder the support

and scaling of small-scale irrigation programs. These are summarized in the following as well as in Table 2.

4.1.1 Key challenges/problems

(1) **Fragmented policies and weak inter-agency coordination:** Government participants frequently cited overlapping mandates, inconsistent policies, and poor coordination among federal, state, and local agencies. This fragmentation leads to bureaucratic delays and confusion in implementing SSI projects. For example, in Kano and Oyo, officials noted that unaligned regulations and siloed efforts slow down project approvals and execution. Abuja stakeholders similarly highlighted fragmented institutional mandates that reduce coherence of SSI interventions nationally.

These challenges are affirmed by participant statements from the three workshops, including these statements from Kano: "*I feel like we're always waiting for political will and approvals. These delays hold back real progress."*; "*We're not communicating efficiently between agencies. This disjointedness makes everything slower and more difficult;*" *and "Investors and partners are hesitant to get involved because the regulations are unclear and constantly changing."*

(2) **Inadequate funding and budget constraints:** All three workshops revealed that government budgets for irrigation and extension services are insufficient relative to needs. Limited funding (and sometimes misallocation of funds) restricts the scale of SSI initiatives. Oyo's officials stressed the lack of both government and private investment in SSI infrastructure as a major barrier. Kano's group echoed that budget limitations impede project implementation. This chronic underfunding undermines long-term planning and support for farmers.

In Abuja, this prioritized constraint was supported by group statements, such as "*Inadequate budgeting and misplacement of priorities in fund allocation*" and "*Lack of synergy among relevant MDAs*".

(3) **Data gaps and weak information systems:** Participants in each region pointed to a lack of up-to-date, reliable data for planning and monitoring SSI. Critical information on water resources, weather, soils, and farmer activities is often missing or not shared across agencies. In Kano, a shortage of skilled staff for data analysis exacerbates this issue. Oyo officials noted limited access to hydrological and meteorological data from national services (NiMet, NIHSA), which hampers evidence-based decision-making. The Abuja workshop likewise identified weak ICT infrastructure and data management systems in government as a structural handicap.

This is supported by statements from Kano: "*How can we make evidence-based decisions when we rely on top-down leadership and don't have access to reliable, up-to-date data*?"; from Abuja: "*Inadequate technology for the dissemination of weather, climatic and hydrological data to the SSI farmers*" and Oyo: "*Concerned about inadequate data affecting decisions*."

(4) **Limited extension capacity:** Especially in Oyo and at the federal level (Abuja), government stakeholders highlighted the insufficient number of extension agents and outdated training as a major constraint. Farmers are not receiving adequate guidance on modern irrigation techniques due to an overextended and under-skilled public extension workforce. This gap contributes to low adoption of SSI innovations at the farm level. Kano's discussions also mentioned capacity deficits, but they primarily focused on data and the technical skills of the staff.

An example includes a statement from Abuja's event: "*Extension Agents are aged, retired and [there is] no recruitment of new Extension Agents*."

(5) **Farmer attitudes and awareness:** Oyo's government group raised that many smallholders exhibit resistance to adopting new irrigation technologies, often due to lack of knowledge about the benefits. Government actors saw this challenge, which originated from the farmer side, as a call to improve outreach and demonstration. (Kano's workshop similarly noted low farmer acceptance of modern methods, though this point was more prominently discussed by the equipment suppliers).

A sample statement from Oyo notes that "*Farmers resist adopting new irrigation technologies*."

(6) **Land and infrastructure constraints**: Region-specific issues also came up. Farmers in Oyo cited the fragmentation of farmlands into small, scattered plots as a hindrance to effective irrigation support and farmer organization. The Oyo participants, and to some extent the Federal participants, emphasized poor rural road infrastructure, making it difficult to access farms and deliver inputs or services. Meanwhile, Abuja's workshop uniquely underscored land tenure insecurity—unclear land rights that discourage investment in irrigation development, particularly affecting women and youth.

A participant from Oyo summarizes this as "*Fragmentation of farmlands complicates intervention*", while a group in Abuja noted "*Inconsistencies in land use systems and ownership*."

In addition to these specific constraints linked to SSI, we also noted, particularly in Kano State but also Oyo that at the beginning of the HCD events, government actors equated irrigation with large-scale irrigation, for which government roles have been relatively well defined, even though, large-scale irrigation investment in sub-Saharan Africa, including Nigeria, accounts for a small share of national expenditures. There was much less familiarity with what SSI entails and how government engagement around SSI is set up. This is also reflected in weak policy structures for SSI, which easily falls through ministerial cracks. While Nigeria's Federal Ministry of Water Resources and Sanitation's Irrigation Directorate is in charge of large-scale irrigation, the Federal Ministry of Agriculture and Food Security supports SSI, but these are typically smaller systems of 20 hectares or more that require infrastructure investment. There are very few to no government efforts to support farmers in acquiring and managing their own irrigation technologies. This division between ministries based on size of irrigated area is not unusual but often leads to suboptimal coordination, planning, and dissemination strategies.

4.1.2 Proposed Solutions and Opportunities

Through the HCD ideation phase, government stakeholders in all three locations co-developed a range of solutions aimed at addressing the above challenges and strengthening the enabling environment for SSI:

(1) **Policy harmonization and coordination platforms:** A unanimous recommendation was to improve coordination across institutions. Participants proposed establishing formal multi-sector coordination bodies or technical working groups that bring together relevant ministries and agencies to align SSI objectives and actions. For example, Kano's workshop suggested an ***inter-ministerial Technical Working Group (TWG)*** to streamline approvals and ensure federal-state-local alignment on irrigation initiatives. Similarly, Oyo and Abuja stakeholders called for unified policy frameworks for SSI so that all actors operate under clear, consistent guidelines rather than conflicting mandates. Such coordination platforms would also facilitate regular communication and data sharing between government, financial institutions, and suppliers.

(2) **Increased funding and innovative financing for public programs:** To tackle budget shortfalls, government groups recommended both raising direct budget allocations for SSI and leveraging outside resources. Solutions included advocating for higher agriculture/irrigation budget shares at federal and state levels and pursuing public-private partnerships (PPPs) and grants to co-fund irrigation projects. Participants in Abuja proposed implementing performance-based budgeting with enhanced transparency to guarantee the efficient use of allocated funds for SSI programs. Additionally, creating incentives (e.g., matching funds, subsidies) for financial institutions to lend for irrigation was considered a way to channel more resources into the sector.

(3) **Centralized data systems and digital tools:** All regions prioritized improvements in data and information management. A key idea was to develop a centralized data platform or repository that integrates essential data—climate, hydrology, soils, farmer registration, market prices—and makes it easily accessible to all stakeholders. This would address the current data fragmentation by consolidating inputs from agencies like NiMet (weather), NIHSA (hydrology), extension surveys, etc., into one mapping and decision-support system. Government agencies also saw value in adopting ICT-based monitoring & evaluation (M&E) tools and dashboards to track SSI project performance in real time. By investing in both data infrastructure and the human capacity to use it (through training), government can enable more evidence-driven planning and rapid response in the irrigation domain.

(4) **Capacity building for extension services**: Strengthening extension was a recurrent theme. Proposed actions included recruiting additional extension officers (with a focus on engaging tech-savvy youth) and upskilling existing staff through targeted training in modern irrigation practices, data analysis, and use of digital advisory tools. Participants envisioned modernizing extension delivery by equipping agents with smartphones or tablets loaded with

the new mapping tool and other apps to provide timely advice to farmers. In Abuja, there was excitement about youth-led digital extension programs—for example, deploying young graduates as "digital extension agents" who use ICT platforms to reach farmers remotely. Building these capacities would help translate the mapping tool's data into actionable guidance on farms.

(5) **Government stakeholders acknowledged the necessity of advocating for broader rural development initiatives that support small-scale industries (SSI).** This includes investing in improving rural road rehabilitation, electricity, and communication infrastructure to ease access to irrigation sites and enable market connectivity. In Abuja, a specific call was made to operationalize the Land Use Act and accelerate land titling, which would especially empower women and youth by securing their land rights for irrigation investments. Additionally, enhancing governance and transparency—for instance, via public dashboards that show the progress of irrigation projects—was suggested to build trust and citizen engagement in these programs.

Table 2. Summary of key challenges faced by government stakeholders in supporting SSI and solutions co-created during HCD workshops in Kano, Oyo, and Abuja

Challenge (Government Agencies)	Co-created Solution Proposals
Fragmented policies and siloed institutions—overlapping mandates and inconsistent SSI regulations causing delays	Establish an inter-agency coordination platform (e.g., multi-ministerial task force) and develop unified SSI policy guidelines to align efforts across federal, state, and local levels.
Inadequate funding and budget misalignment—insufficient and erratic funding for SSI programs, limiting scale	Increase government budget allocations for irrigation; adopt performance-based budgeting with transparent audits. Leverage PPP schemes, grants, and mobilize additional funding and reduce risk in de-risk investments.
Data gaps and poor information systems—lack of updated agro-climatic data, farmer databases, and analytics capacity	Build a centralized data platform consolidating climatic, hydrological, and farmer data. Invest in ICT tools (digital M&E, GIS mapping) and train staff in data analysis for evidence-based planning.
Weak extension services and technical capacity—too few extension agents and outdated skills, hindering farmer support	Recruit and train a new cadre of extension workers (leveraging youth) and introduce digital extension approaches. Provide continuous training on modern SSI techniques and the use of mapping tools for on-farm advisory services.
Farmer reluctance to adopt SSI innovations—low awareness and trust among farmers for new irrigation technologies	Implement farmer sensitization and training programs through extension services to demonstrate SSI benefits. Organize field days and demo plots to build farmer confidence in new technologies.
Land fragmentation & tenure issues—small, scattered plots (e.g., Oyo) and unclear land rights (e.g., Abuja) hindering investments	Cluster small farms into irrigation schemes or cooperatives for easier support. Strengthen land tenure policies—implement land titling and Land Use Act provisions, especially to include women and youth.
Poor rural infrastructure—bad roads, limited power, and connectivity—raising costs and limiting project access (noted in Oyo/Abuja)	Prioritize rural infrastructure development (farm-to-market roads, rural electrification, and internet access) in parallel with SSI initiatives. Coordinate with broader infrastructure programs to target key irrigation areas.

Overall, government actors across all regions recognized that achieving scale in small-scale irrigation requires internal reforms and stronger coordination on their part. The solutions they proposed—from technical working groups and data systems to budget reforms and capacity building—form a blueprint for creating an enabling institutional environment. These changes are foundational to the successful increase of SSI in Nigeria.

4.2 Financial Institutions

The HCD workshops engaged banks and financial institutions (including agricultural development banks, commercial banks, and microfinance providers) to understand why lending for SSI remains limited and how to improve farmers' access to finance. Participants from financial institutions in Kano, Oyo, and Abuja described a range of financial and risk-related challenges that converge on the fundamental issue of making SSI lending bankable and sustainable. A summary of challenges and solutions is presented in Table 3.

4.2.1 Key challenges/problems

(1) **High default risk and limited farmer creditworthiness**: Lenders in all regions see smallholder farmers as risky borrowers. Factors such as unpredictable weather impacting yields, price volatility, and farmers' irregular incomes drive high default rates were reported. Insecurity in certain areas (e.g., conflict or banditry in parts of Oyo and northern Nigeria) exacerbates loan repayment problems as farmers may abandon their farms or lose assets. Financial actors also noted that many farmers lack formal credit histories or records, making it challenging to assess creditworthiness. This overall high-risk perception leads banks to charge very high interest rates or avoid agricultural lending altogether.

Statements reflecting this assessment by the financial sector include (from Kano State): "*The costs of processing loans are eating into our margins, making it harder to sustain lending to smallholders*"; " *We don't have enough concrete data to assess whether these loans will be repaid or yield returns*"; and "*We need improved data and risk models to better assess the potential of SSI investments*".

(2) **Stringent collateral requirements and limited collateral assets:** Traditional lending models require collateral that small-scale farmers often do not have (e.g., land titles, houses). Collateral limitations in Kano highlighted this challenge, preventing many farmers from qualifying for loans. Oyo bankers similarly mentioned restrictive loan conditions, implying collateral and guarantor demands that most farmers cannot meet. Without collateral or credit guarantees, lenders are reluctant to approve irrigation loans, especially for resource-poor farmers or women who rarely hold land titles.

This finding is supported by statements, such as from Oyo: "*Collateral requirements exclud[e] smallholders*" and Kano: "*Most farmers don't have land titles or assets to offer as collateral."*

(3) **Lack of awareness and low demand for irrigation credit by farmers:** A somewhat unexpected finding (notably in Oyo) was that ***few*** farmers actively seek irrigation financing, partly due to their low awareness of such financial products or their skepticism about taking loans. Because many smallholders are not familiar with the potential benefits of irrigation or have had negative experiences with loans, uptake of existing credit schemes is low. This in turn dampens banks' interest in developing tailored products since perceived demand is weak.

(4) **Lack of awareness by financial institutions of the SSI sector:** At the same time, there is a lack of understanding, on the part of the financial sector, of risk reductions associated with SSI; and a lack of information of the profitability of SSI compared to rainfed agriculture.

Statements supporting this include "*The risks are too high, and without proper data, we cannot make informed decisions"*; "*We don't fully understand the sector nor the farmers; how can we invest in something we don't know well?*"; and "*There's a need for more localized data that shows the actual returns on small-scale irrigation projects"* (both from the Kano financial sector HCD).

(5) **Inappropriate loan products (mismatch with agricultural cycles):** Existing financial products were criticized for not aligning with the seasonal nature of farming. For instance, standard loans may require monthly repayments, whereas farmers have seasonal cash flows. Kano observed that current products neglect to consider agricultural cycles, rendering them unsuitable for SSI investments. This mismatch can lead to repayment stress and defaults even for willing farmers, because repayment schedules don't wait for harvest.

(6) **High lending rates and macroeconomic pressures**: Especially in Kano's context, bankers pointed to macroeconomic factors like the Monetary Policy Rate (MPR) increases driving up lending interest rates. High interest (often well above 20% annually) makes irrigation loans unaffordable for farmers. Financial institutions feel pressure to maintain rates given inflation and central bank policies, even though it prices out many would-be borrowers.

(7) Operational and infrastructure challenges: Reaching remote rural clients. Participants from Oyo noted that inadequate digital banking infrastructure and a reduced presence of rural banks, with some agricultural bank branches either closed or understaffed, limit farmers' access to credit services. Poor IT systems mean loan processing and monitoring are inefficient, raising transaction costs. Moreover, security concerns (theft, attacks on field agents) in certain areas make it dangerous and expensive to service loans on the ground.

(8) **Limited capital and liquidity for agricultural lending:** Particularly in Oyo, it was mentioned that specialized agricultural banks have an insufficient capital base to meet the loan demand if they were to scale up SSI financing. Without external investment or recapitalization, these institutions struggle to expand their loan portfolios for irrigation.

(9) **Communication gaps and siloed efforts:** Another issue raised (Oyo) was the poor communication and collaboration between financial institutions and government programs. Banks might not be aware of government initiatives or subsidies that could support SSI, and vice versa, leading to missed opportunities for partnership (for example, coordinating and identifying credible farmer groups).

(10) **Overall regulatory challenges in the finance sector.** Participants from Kano, in particular, pointed to outdated and complex regulations that restrict financial institutions' ability to innovate and offer flexible lending solutions, hindering the expansion of financing for SSI projects.

4.2.2 Proposed Solutions and Opportunities:

The financial stakeholders proposed innovative ways to de-risk lending and increase the viability of financing SSI. Through the ideation discussions, they proposed several strategies to improve credit access and financial sustainability for small-scale irrigation.

(1) **Improving risk assessment for SSI investments:** A critical issue facing SSI projects is the need for more effective risk management, particularly given the inherent uncertainties of agriculture, such as variable weather patterns and fluctuating market conditions. One potential solution is the development of data-driven risk assessment tools. A digital platform could be created that integrates various datasets, including local agricultural data, historical weather patterns, and crop yield forecasts, to provide real-time, data-backed risk assessments for financial institutions. This platform would help banks and investors make more informed decisions by offering detailed insights into the risks associated with specific SSI projects. Additionally, a context-specific risk scoring system could be developed to evaluate potential risks using parameters such as historical yields, market conditions, and external environmental factors. By continuously updating this risk score based on fresh data inputs, it would provide a dynamic, accurate representation of project risk, enabling better decision-making for investors and financial institutions.

(2) **Innovative risk-sharing and guarantee mechanisms:** To mitigate the high default risk, a popular idea was to introduce ***Credit Risk Guarantees (CRGs)*** or insurance schemes that share the risk of lending with third parties. For example, a government-backed guarantee fund or partnering with development finance institutions could cover a portion of losses if farmers default, giving banks more confidence to lend at lower interest rates. In Abuja, stakeholders explicitly recommended deploying CRG-backed loan schemes to encourage financial institutions to lend to smallholders. Similarly, index-based crop insurance was highlighted—bundling insurance with loans so that drought or losses due to flood are compensated quickly, thereby protecting both farmers and banks. Ensuring timely insurance payouts was seen as crucial to maintaining trust in these risk mitigation tools.

(3) **Alternative collateral and group lending models:** To overcome conventional collateral hurdles, participants proposed alternative collateralization strategies. One such approach is group lending, or cooperative-based loans, where farmers form groups or cooperatives that collectively guarantee each other. This leverages social capital and peer pressure to improve repayment and can substitute for physical collateral. Kano's workshop mentioned using ***group guarantees*** as a model (e.g., cooperative societies guaranteeing member loans). Another idea was to tie loans to the financed asset—for instance, using irrigation equipment itself or future crop output as a form of collateral (with buy-back or lien arrangements). Financial stakeholders also stressed the importance of land titles (where available) and advocated for accelerating land tenure reforms, so that more farmers have bankable assets.

(4) **Tailored financial products and flexible terms:** The need to design loan products suited to agriculture was emphasized. Proposed solutions included offering ***seasonal repayment schedules*** (e.g., repayments only during harvest periods) and grace periods aligning with crop cycles. In Kano, participants suggested creating seasonal loan products specifically for SSI, where the payment timelines correspond to planting and harvest seasons. Also, longer-tenure loans or lines of credit for irrigation equipment purchases could ease the burden, as opposed to short-term credit. Oyo's group advocated for increasing the overall tenor and amount of loanable funds dedicated to irrigation, potentially through dedicated funding windows or quotas in banks.

(5) **Digital finance and Fintech solutions:** By embracing digital platforms, transaction costs can be reduced and services to remote farmers enhanced. Ideas included rolling out robust mobile/online banking platforms in agricultural banks to enable farmers to apply for and manage loans via mobile devices. Expanding mobile money integration would help with disbursement and collection of repayments, reducing the need for physical bank branches. Kano introduced the concept of a digital platform that integrates weather, yield, and market data for real-time risk scoring. Such a platform could feed into credit scoring models to more accurately evaluate farmer risk (for example, by using satellite data on drought or yield forecasts to adjust lending decisions). This aligns with Abuja stakeholders calling for digitized loan tracking and credit scoring systems, leveraging data to improve lending decisions. Overall, fintech innovations were viewed as key enablers to reach more farmers efficiently and manage risks better.

(6) **Strengthening rural banking infrastructure and capacity:** The workshops also produced recommendations to reinforce the institutional capacity of lenders. In Oyo, participants urged reopening closed rural bank branches and hiring/rehabilitating specialized staff for agricultural finance. Having more field loan officers and agri-finance specialists can improve loan appraisal and recovery in farming communities. Some suggested establishing dedicated SSI finance units or desks within banks. Additionally, training bank staff on the specifics of agricultural lending and irrigation economics would help in designing appropriate

loan packages. Enhanced security measures (such as using secure agent banking or working with local vigilante groups for safety) were proposed to tackle the insecurity problem that hampers loan recovery in volatile areas.

(7) **Farmer awareness and financial literacy:** Financial institutions recognized they have a role in boosting demand by educating farmers. A cross-cutting solution was ***to collaborate with extension services and NGOs to raise farmer awareness*** about credit options for irrigation and improve basic financial literacy. This could involve workshops for farmers on how irrigation loans work and their benefits and obligations. In Abuja, it was suggested to mandate borrower training programs before loan disbursement—ensuring farmers understand loan terms, budgeting, and the importance of repayment. By improving trust and knowledge, farmers may be more willing to take on productive credit and more capable of managing it wisely (reducing issues like loan diversion to nonfarm uses).

(8) **Collaboration with government and value-chain actors:** To bridge communication gaps, participants recommended setting up multi-stakeholder forums or regular meetings between banks, government agencies, and agricultural extension or farmer groups. This would allow the sharing of information on upcoming government programs, subsidies, or infrastructure developments that could affect agricultural risks and opportunities. Also, banks can partner with verified input suppliers or irrigation equipment dealers such that loans are directly tied to purchasing quality equipment (reducing the risk of farmers buying substandard pumps that then fail). Abuja's group proposed vendor accreditation systems and linking finance to certified suppliers with warranties, ensuring that credit is used for its intended purpose and results in reliable investments. Such coordination can improve outcomes for all sides.

Table 3. Summary of key challenges faced by financial institutions in expanding SSI lending and solutions (ideation) from HCD workshops.

Challenge (Financial Institutions)	Co-Created Solution Proposals
Limited understanding of SSI sector by financial institutions	Improved data platforms that helps improve risk assessments of loans in the SSI sector
High default risk & loan losses—Frequent farmer defaults due to weather, market, or security shocks	Introduce risk-sharing mechanisms: establish a Credit Risk Guarantee (CRG) fund to back SSI loans. Bundle loans with index-based crop insurance for drought/flood protection and fast-track insurance claim payouts.
Collateral and access constraints—Farmers lack traditional collateral (land titles/assets) to secure loans	Adopt alternative collateral models: use group guarantees or cooperative lending whereby farmer groups mutually guarantee loans. Explore warehouse receipts or equipment-leasing models. Implement policies for land titling to increase farmers' collateral assets over the long term.
Misaligned loan terms—Products with strict terms (high interest, frequent payments) not suited to seasonal farming	Develop tailored loan products: seasonal repayment schedules aligned with harvests, lower-interest long-term loans for equipment purchase, and grace periods during crop establishment. Increase concessional funding to allow single-digit interest rates for SSI.
Weak rural banking infrastructure—limited digital services, branch closures, and staff shortages in rural areas	Invest in digital banking platforms (mobile apps, USSD services) at agricultural banks to reach farmers remotely. Reopen or set up dedicated rural finance branches, and train/assign more loan officers specializing in agribusiness finance. Enhance field security via partnerships with community security outfits.
Low farmer awareness & financial literacy – Few farmers seek loans due to lack of information or trust	Improve outreach and education: coordinate with extension agents to promote irrigation loan offerings and educate farmers on benefits. Require pre-loan training for borrowers on financial management and proper loan use (in local languages, using simple media) to improve credit culture.
Lack of coordination with government & value chain—little communication between banks and agri-programs/suppliers	Establish agri-finance forums that regularly bring together banks, government (agriculture & irrigation agencies), and farmer representatives to align financing with programs. Implement vendor accreditation so banks finance only quality-assured equipment, disbursing through partner dealers to ensure proper use of funds.
Limited capital for agri-lending—Specialized banks lack sufficient funds to expand SSI loans	Mobilize capital via government or donor recapitalization of agricultural banks and through impact investment funds targeting irrigation. Encourage deposit growth in rural areas by offering incentives and tap into climate finance sources to subsidize SSI credit.

Through these solutions, financial stakeholders conveyed a willingness to engage more deeply in the SSI sector if the right policy and institutional structures are in place. The consensus was that innovative financial models—supported by government guarantees, better information through supporting risk assessment tools, and collaboration with other actors—could unlock credit for many smallholders who are currently underserved.

4.3 Irrigation Equipment Suppliers

The third stakeholder group—irrigation equipment suppliers and distributors—provided the private sector perspective on the supply chain for irrigation technologies. Participants included local dealers, importers, and technicians dealing with pumps, drip irrigation kits, sprinklers, solar irrigation systems, etc. Their discussions shed light on the market and logistical challenges of making modern irrigation equipment available, affordable, and serviceable for small-scale farmers across Nigeria. The HCD workshops in Kano, Oyo, and Abuja revealed several common pain points as well as some region-specific issues for equipment suppliers. These are discussed in the below and summarized in Table 5.

4.3.1 Key challenges

(1) **Import barriers and high costs:** Suppliers unanimously pointed to difficulties in importing irrigation equipment. In Kano, equipment dealers noted that corruption and inefficiencies in import processes were driving up costs and causing long delays. Oyo participants similarly cited customs inefficiencies—inconsistent tariffs, extortion, and delays at ports—as creating bottlenecks and inflating prices. Abuja's suppliers highlighted excessive bureaucracy and unpredictable import tariffs as major hurdles. Additionally, FOREX (foreign exchange) volatility has made importing equipment increasingly expensive. Oyo participants noted that unstable exchange rates significantly raise equipment costs, reducing affordability for farmers. Abuja suppliers echoed that currency fluctuations make pricing and planning difficult ("import costs are unpredictable and rising"). These import-related challenges limit the availability of quality irrigation technologies in the local market and squeeze supplier profit margins.

Supporting statements include, from Kano include: "*Corruption at the importation stage adds unnecessary costs and delays, which erodes our profit margins and stifles the growth of the market*" and "*The cost of equipment is too high for many farmers. We need government intervention in subsidizing exchange rates and removing tariffs to make equipment affordable*", while Abuja participants noted "*Import tariffs and bureaucracy*" and "*FOREX*" as key challenges.

(2) **Limited access to finance for suppliers:** Particularly in Oyo and Abuja, equipment distributors reported struggling to get capital or credit to maintain inventory of irrigation products. Because many suppliers are small/medium enterprises, they often lack the funds to import in bulk or offer pay-later sales to farmers. Oyo's group identified limited access to affordable finance as a key constraint that restricts their ability to stock equipment and expand to new markets. Without soft loans or credit lines, suppliers cannot expand their operations or offer competitive prices. In Kano's workshop this issue was not explicitly highlighted in the top challenges list, but it is a broader trend in the sector.

(3) **Uncertain market demand**: Suppliers, particularly in Kano noted that they do not have reliable data on farmer needs, regional demand, or cropping patterns, which makes it

difficult to forecast sales or manage inventories. Insufficient data on local needs and cropping patterns makes it difficult to forecast demand, causing inventory management challenges.

(4) **Low farmer adoption and awareness of modern technologies:** Suppliers observe that many smallholders are either unaware of or hesitant to use modern irrigation solutions like drip or solar pumps. Kano's suppliers called out low acceptance of modern technologies—farmers often stick to traditional methods because they lack understanding of how new systems work or doubt their benefits. Oyo's group similarly noted that inadequate technical knowledge among farmers leads to misuse or underutilization of irrigation equipment. This low demand due to limited awareness creates a vicious cycle: suppliers are less inclined to stock advanced equipment if farmers aren't asking for it. It was also mentioned that communication between suppliers and end-users is weak, so feedback on products or performance rarely reaches the suppliers to help improve offerings.

This is supported by participants from Kano noting: "*There's a lot of untapped potential in the small-scale irrigation market. If we can solve the awareness and training problems, we could see massive growth*," while Oyo participants noted "*limited […] technical skills [of farmers]*."

(5) **Lack of maintenance services and spare parts**: A critical challenge in all regions is the absence of robust after-sales support for irrigation devices. Farmers may encounter challenges in installation, maintenance, and repairs once they purchase equipment. Kano suppliers highlighted the lack of spare parts and maintenance support—essential components are hard to find locally, and there are few trained technicians in rural areas. This leads to frequent breakdowns and abandoned equipment, undermining trust in the technology. Abuja's discussion reinforced that no rural repair ecosystem currently exists; farmers in remote areas have nowhere to go to service their pumps or replace parts, drastically reducing equipment lifespan. Without reliable maintenance, even well-intended irrigation investments can fail, so this is a major barrier to sustainable scaling.

As participants in Kano noted, "*It's hard to keep equipment running because spare parts are often in short supply, which impacts our ability to offer good after-sales service*," and "*There is not enough local manpower capacity to support ongoing maintenance or repairs. It discourages customers from making purchases if they feel they can't maintain the equipment.*"

(6) **Infrastructure and security challenges in distribution**: Similar to other stakeholders, suppliers are affected by poor infrastructure. They must deliver heavy equipment to rural communities where roads may be bad or electricity for running pumps is inconsistent. Abuja suppliers mentioned weak transport and connectivity networks—bad roads, lack of power, and limited internet in rural areas increase the cost of doing business and hinder support services. Insecurity is another distribution challenge: Oyo's group noted that security threats (theft, banditry) during transport can disrupt logistics and endanger staff. Abuja likewise listed supply chain disruptions in conflict-prone zones—meaning certain areas are effectively

off-limits or high-risk for suppliers due to unrest. These factors make it challenging to build a wide-reaching supply chain for irrigation tools.

(7) **Regulatory issues (standards and quality control):** An issue raised in Oyo was the intervention of the Standards Organization of Nigeria (SON). Suppliers complained that sudden regulatory actions by SON (e.g., impounding goods over standards compliance at wholesale and retail levels) sometimes interrupt distribution. Although quality control holds significant importance, its implementation, if not streamlined, can cause disruption. There is also the broader matter of ensuring quality products in the market—Abuja's financial stakeholders even pointed out that substandard inputs reduce farm productivity and erode trust, which aligns with suppliers' interest in better regulation of equipment quality.

(8) **Limited availability of solar-powered irrigation systems in the local market** (highlighted by Oyo participants). Solar pumps and drip systems can be game-changers for off-grid farmers, but they are not yet widely stocked by suppliers, possibly due to high upfront costs and low demand. This limits farmers' choices mostly to diesel pumps or petrol pumps, which have higher operating costs. Promoting solar tech requires overcoming both awareness and cost hurdles, but suppliers see potential if supported.

(9) **Gender disparity in access to SSI:** The Abuja workshop raised an important inclusion issue - women farmers struggle to access irrigation equipment due to male-dominated distribution channels and cultural biases. Women often have less mobility, capital, or networks to obtain equipment, and sales practices may not target or accommodate them. Participants also noted that some women farmers have no direct access to ground water and land. This challenge was not explicitly discussed in Kano or Oyo in our records, but it is a significant factor nationally.

4.3.2 Proposed Solutions and Opportunities

The irrigation suppliers, being practical businesspeople, focused on solutions that would improve the supply chain's efficiency, reduce costs, and create a more favorable market for both sellers and buyers of irrigation technologies.

(1) **Streamlining import and customs processes**: To make importing easier, participants suggested changes like quicker customs checks for irrigation equipment and lowering or removing import taxes. They also recommended giving special treatment to essential irrigation technologies, such as setting up a special "green lane" at ports for irrigation kits to speed up inspections and paperwork. Greater transparency in import protocols was also emphasized as a means to cut down corruption (e.g., using electronic tracking and clear tariff schedules to eliminate unofficial fees). Kano's solution was to strengthen import governance and oversight mechanisms, ensuring quality equipment can enter without unethical delays. By implementing these measures, we can reduce costs that farmers would otherwise bear and enhance the timely availability of technologies.

(2) **Improved access to foreign exchange and local manufacturing**: Since FOREX volatility is making imports expensive, one recommendation (especially from Abuja participants) was for the Central Bank to provide a special foreign exchange window or concession for certified agro-input and irrigation equipment importers. By allowing prioritized access to US dollars at stable rates, suppliers could plan and price their products more reliably. In the longer term, suppliers proposed incentivizing local assembly or manufacturing of irrigation equipment. If pumps or drip components can be produced or at least assembled domestically (perhaps under license from international manufacturers), it would reduce dependency on imports and foreign exchange. This might involve tax breaks for setting up local manufacturing plants or public-private partnerships to produce affordable equipment locally.

(3) **Financial support for suppliers and end-users:** Recognizing the financing gap, workshop participants suggested mechanisms to inject capital into the supply chain. One idea was for government or development banks to offer soft loans or credit facilities to irrigation suppliers so they can stock more inventory and offer financing to customers. For instance, a low-interest credit line could be established for agro-dealer SMEs to import equipment in larger quantities (driving unit costs down). Another approach is inventory financing platforms or guarantee schemes where banks use the equipment as collateral and finance suppliers' inventory (this was hinted at in Abuja: "*launch SME-focused credit schemes and inventory financing via commercial banks and DFIs*"). On the end-user side, suppliers were in favor of any program that helps farmers afford equipment—such as hire-purchase arrangements, vouchers, or subsidy programs—since that directly boosts their sales.

(4) **Enhancing farmer awareness and training:** To generate demand and ensure proper use of products, suppliers saw the need for extensive farmer outreach and education. They proposed conducting promotional demonstrations of modern irrigation technologies in collaboration with government extension services. Oyo's solution set included expanding technical training and providing user manuals in local languages to farmers. This would demystify new equipment like drip irrigation, teaching farmers installation and maintenance basics. Regular feedback forums and communication channels between farmers and suppliers were also suggested so that user experiences inform product improvements and after-sales support. Essentially, suppliers realize that an informed customer base is key to scaling adoption—when farmers see the benefits and know how to use the tools, they are more likely to invest. Kano, focusing on drip irrigation, proposed comprehensive awareness campaigns, coupled with on-the-ground demonstrations on farms, to educate farmers on the benefits and ease of use of drip irrigation systems. Promotional activities organized by suppliers, supported by government initiatives, would further encourage uptake. These activities should focus on showcasing the tangible benefits of drip irrigation, such as water conservation and increased crop yields, thereby fostering a cultural shift toward this technology.

(5) **Building local maintenance and service networks:** To address the after-sales gap, participants strongly recommended developing a local servicing ecosystem. This could entail establishing rural service centers or hubs in farming communities where spare parts are stocked and repair services are offered. Suppliers and the government could partner to train local youths or technicians in equipment repair and maintenance, creating jobs and ensuring farmers have nearby support. Kano's group specifically proposed binding agreements between importers and suppliers to ensure continuous spare part supply in local markets. Abuja's workshop expanded on this with the idea of mobile service networks—possibly technicians on motorbikes or vans who can travel to villages to fix pumps. By guaranteeing spare parts availability and skilled repair services, the lifespan of irrigation equipment would increase, making the investment far more worthwhile for farmers. This also builds farmer confidence knowing that help is accessible when breakdowns occur.

(6) **Security and logistics improvements:** Given the concerns around insecurity and transport, suppliers suggested working with authorities to provide security escorts or arrangements for equipment delivery in risky areas. For instance, deploying agro-rangers or coordinating with local vigilante groups can protect shipments and infrastructure in transit. They also pointed to the need for better infrastructure as a shared responsibility—urging the government to improve roads and extend electricity to rural areas, which would lower the cost of supplying and maintaining irrigation devices. In the interim, promoting solar-powered systems was seen as one way to bypass the lack of grid power (and indeed Oyo's group wanted a push for solar irrigation to offset diesel costs and the unreliability of fuel).

(7) **Focus on inclusive and gender-responsive distribution:** To ensure women farmers benefit, Abuja participants recommended designing gender-inclusive distribution models. This could mean recruiting female sales agents, forming women-centric irrigation user groups, or offering special financing schemes for women to acquire equipment. The suggestion of women-led irrigation cooperatives came up, whereby groups of women farmers collectively purchase and manage irrigation assets with support from NGOs or microfinance, which could be facilitated by suppliers providing training and tailored packages. Additionally, adapting marketing and training approaches to be more accessible for women (for example, scheduling training at times women can attend and addressing cultural constraints) was advised. Such measures help close the gender gap in technology adoption.

Table 4. Summary of key challenges for irrigation equipment suppliers and distributors, with solution concepts from the workshops

Challenge (Equipment Suppliers)	Co-Created Solution Proposals
Corruption, delays & high costs in import—Cumbersome customs, unofficial fees, and taxes inflate equipment cost	Streamline import processes: institute a fast-track clearance system for irrigation equipment and waive/reduce import duties on critical components. Increase transparency with e-customs systems to eliminate rent-seeking, ensuring timely and lower-cost imports.
Foreign exchange shortages and exchange rate instability raising prices—Fluctuating exchange rates make equipment unaffordable	Provide preferential forex access for certified agri-tech importers (e.g., a stable Central Bank forex window). Encourage local assembly/manufacturing of irrigation equipment through incentives, reducing reliance on imports and currency exchange.
High cost of capital for distributors—Suppliers can't stock inventory or offer credit due to lack of financing	Offer soft loans and credit lines to irrigation SMEs via development banks or government programs. Implement inventory-financing schemes where banks finance supplier stock (with equipment as collateral). Facilitate supplier access to grants or matching funds to expand distribution networks.
Low farmer awareness and adoption—farmers unfamiliar or unconvinced about modern SSI tech	Conduct extensive outreach: demonstration plots, field days, and training sessions to showcase the benefits of drip, sprinkler, and solar pumps. Distribute easy-to-understand user manuals and leverage radio/TV to promote SSI technology. Establish feedback loops (forums, helplines) so farmers can voice needs and success stories.
Lack of spare parts and maintenance services—Difficult to repair equipment locally, causing downtime	Develop local service centers in farming areas stocking spare parts and employing trained technicians. Enforce supplier agreements to guarantee continuous spare part supply and warranty service. Train mobile technician teams to provide on-site repair in remote villages, minimizing equipment downtime.
Poor infrastructure & logistics—Bad roads and no electricity hinder distribution and support	Work with the government to improve rural infrastructure (farm-to-market roads; rural electrification or solar alternatives for energy). In the short term, use innovative delivery strategies like solar-powered cold chains for parts and coordinate with local communities for secure storage and distribution points. Implement security escorts as needed.
Gender gap in equipment access—Women farmers often excluded or underserved in current models	Adopt gender-inclusive marketing and support: hire/train female sales reps and extension agents to engage women farmers. Form women's irrigation cooperatives and offer group discounts or financing targeted at female farmers. Design equipment packages and training with women's needs in mind (e.g., lighter-weight equipment).
Regulatory disruptions (SON standards)—Quality checks causing delays or uncertainty (Oyo)	Pre-import testing and certification: work with SON to certify equipment models before import, so they won't be held up at entry. Establish clear standards for irrigation equipment, and ensure suppliers are aware and compliant to avoid ad hoc enforcement actions.

The suppliers' insights complete the picture of the SSI ecosystem's bottlenecks by highlighting supply-side and market dynamics. Their proposed solutions focus on creating a more efficient and supportive market system—one with lower costs, reliable supply chains, informed customers, and support services.

5. Cross-Cutting Themes and Challenges

Across the diverse stakeholder discussions in Kano, Oyo, and Abuja, several cross-cutting themes emerged. These are overarching issues that affect all aspects of the SSI value chain—from policymaking to farm-level practices—and therefore are critical areas of focus for the successful development of tools and other measures to support intermediary actors in their roles as SSI enablers. The key cross-cutting themes identified include data and information gaps, policy/institutional coordination, innovative financing, extension capacity, and gender inclusion, among others:

(1) **Data Gaps and Digital Tools:** All workshops underscored significant gaps in data availability, quality, and accessibility for decision-making in small-scale irrigation. Government planners lack reliable, up-to-date datasets on climate, water resources, soils, and farmer locations, which hampers effective targeting and monitoring. Financial institutions similarly suffer from limited data on farmers' credit history, farm productivity, and localized risk factors, including information to what extent irrigation reduces default risk, which makes lending decisions difficult.

Suppliers would benefit from market data (e.g., where irrigation is expanding), but such information is not readily accessible. The call to action was clear: develop integrated data systems and digital platforms to collect, share, and analyze key information.

For instance, stakeholders proposed geo-tagged farmer registries and agro-climatic databases that are publicly available. They also highlighted the value of ICT innovations—from digital M&E dashboards in government to mobile apps for loan tracking in finance and possibly GIS-based market maps for suppliers. This suggests the need for a central data hub that aggregates various data layers (climate, water, land use, demographics) and presents them in an actionable format. By filling data gaps and making information visually accessible via maps and analytics, the tool can enable evidence-based decisions and improve transparency across the board.

(2) **Policy Harmonization and Institutional Coordination:** Fragmented and incoherent policy environments were repeatedly mentioned in all regions as a fundamental barrier. Currently, different government agencies (agriculture, water, finance, environment) may have their own SSI programs or regulations that are not aligned, leading to overlaps or contradictions. Similarly, lack of coordination between government, financial bodies, and the private sector means opportunities for synergy are missed. As a cross-cutting solution, stakeholders advocated for policy harmonization—creating unified guidelines for SSI

development that all agencies adhere to—and for formal coordination mechanisms that bring stakeholders regularly together. The idea of a ***national or state-level SSI Coordination Platform or Working Group*** emerged several times during the HCD workshops. This platform would serve to align strategy, standardize approaches (e.g., one national standard for small-scale irrigation projects), and facilitate multi-stakeholder communication.

Such a coordinating body could also be in charge of a data platform in support of intermediary actors and farmers directly. Additionally, clear policies around data sharing (e.g., requiring agencies like NiMet to openly disseminate data) were highlighted, which is vital for improving information quantity and quality in support of SSI expansion. In short, institutional alignment is needed to ensure that any tools and measures developed in support of intermediary actors becomes a shared reference and is not isolated within one department. Harmonized policy also extends to areas like import regulations and financial policies—such consistency supports the enabling environment of SSI.

(3) **Innovative Financing and Investment:** Financing issues cut across stakeholders—affecting governments (needing funds for projects), farmers (needing credit), and suppliers (needing capital). Traditional financing approaches have fallen short in supporting SSI expansion. Hence, innovation in financing emerged as a cross-cutting theme. This includes developing new financial products (like the seasonal loans, equipment leasing, micro-insurance) and leveraging partnerships to mobilize resources (e.g., blending public and private funds). For instance, public-private partnerships were suggested to fund infrastructure and equipment provision in some workshops. Interest rate subsidies or guarantee funds were cross-cutting recommendations to make agricultural loans more attractive to both lenders and borrowers.

From the suppliers' side, calls for financial support mechanisms indicate that without affordable credit up and down the value chain, adoption will lag. The mapping tool can aid financing by identifying priority investment zones—areas where irrigation potential is high and returns on investment could be significant—thus guiding where banks or government grants should focus. Moreover, if the tool can integrate financial risk indicators (e.g., drought frequency maps, food risk, yield variability data), it becomes a practical risk assessment aid for lenders and insurers. A cross-cutting message was that financial innovation must go together with technical innovation, meaning that solving irrigation challenges requires creative funding solutions as much as engineering solutions. A platform with information on available finance mechanisms and data that supports the development of financial products would help address this cross-cutting concern.

(4) **Extension and Capacity Building:** The theme of human capacity—particularly the strength of agricultural extension and advisory services—emerged in all workshops as central to bridging the gap between technology and users. Extension agents aggregate

challenges that farmers face and can support farmers with information on government programs, location of equipment suppliers, as well as insights on agricultural credit programs. Extension workers, training programs, and information dissemination efforts are thus the connective tissue that links policy to on-farm action. It was noted that without adequate extension support, farmers do not learn about new tools, cannot troubleshoot issues, and generally hesitate to change practices. Thus, improving extension capacity is a universal need. This includes both quantitative aspects (hiring more extension agents to achieve better coverage, as Nigeria's extension agent-to-farmer ratio is currently very low) and qualitative aspects (upskilling agents in irrigation-specific knowledge and digital literacy). In many suggestions, digital technology is leveraged to enhance extension—for example, using mobile advisory services or youth-led ICT-based extension as mentioned in Abuja.

This suggests that a platform or database in support of SSI expansion should be designed with extension agents as key users in mind. The interface and outputs should cater to their needs – perhaps providing localized advisory messages or simplified maps that they can easily communicate to farmers. Training programs will be needed to ensure extension staff know-how to interpret and use the tool's data. Furthermore, extension services can serve as a feedback mechanism, reporting field data back into the system (crowdsourcing observations on water levels, cropping patterns, etc.). All stakeholders agreed that capacity building—whether it is government analysts learning GIS, bank officers learning agri-finance and the risk-reducing features of irrigation, or technicians learning pump repair—is essential to make any new system work. Therefore, investments in capacity building are a cross-cutting recommendation that accompanies the introduction of the mapping tool.

(5) **Gender Inclusion and Social Equity:** While not equally emphasized in every state, the importance of addressing gender disparities and ensuring inclusive access was clearly a cross-cutting consideration, especially at the national level. Women play a significant role in agriculture in Nigeria, yet they face greater barriers in accessing land, credit, information, and technology. The Abuja workshop explicitly pointed out that SSI scaling will not be fully successful unless gender-based constraints are recognized and addressed—be it women's insecure land rights limiting their willingness to invest in irrigation, or the fact that extension and financial services often bypass women. As a result, stakeholders recommended measures like gender-sensitive training and financing programs, promotion of women-led irrigation groups, and ensuring women are actively included in any new initiatives.

To ensure that women's concerns are considered any platforms and tools to support scaling of SSI should strive to incorporate sex-disaggregated data (if available, e.g., mapping where female-headed farms are located or highlighting regions with gender gaps in irrigation access). Moreover, gender experts need to be consulted on data entering any tools or platforms. During implementation, special efforts should be made to train women farmers on using information from any platforms or tools developed and to recruit women in the

development and dissemination process (for instance, as extension intermediaries or data collectors).

Gender inclusion as a theme also extends to youth and other marginalized groups, creating opportunities for young professionals (like the youth extension agent's idea) or ensuring interventions reach poorer, less literate farmers. The cross-cutting message is that inclusivity must be baked into the design of solutions so that the benefits of SSI expansion and the SSI suitability maps and tools do not only accrue to well-resourced or well-connected groups.

(6) **Infrastructure and Enabling Environment:** Although the prompt specifically listed the above themes, it's worth noting that infrastructure (roads, energy, storage facilities) and governance (transparency, accountability) were also recurrent cross-cutting issues. Poor infrastructure underlies many challenges for all stakeholders—it limits market access for farmers, increases operational costs for banks and suppliers, and makes government support delivery difficult. Therefore, improving infrastructure (especially rural roads and electrification) is a broader development imperative that complements all specific SSI efforts.

Similarly, improving governance and accountability (through things like public dashboards, citizen feedback loops) was discussed to ensure the proper implementation of policies and projects. While the mapping tool cannot build roads, it can help map infrastructure gaps and support advocacy for those investments. It can also enhance transparency by providing openly accessible data on where interventions are happening and what results are achieved, thereby strengthening accountability.

In summary, these cross-cutting themes highlight that scaling SSI requires systemic changes and multi-faceted strategies that go beyond the development of supportive platforms, information networks and decision support tools.

6. From Intermediary Actor Solutions to Decision Support Tools

Building on the integrated insights from the HCD workshops, this section outlines actionable recommendations for data, platforms and tools that reflect challenges and solutions identified by a diverse set of intermediary stakeholders during nine workshops in three regions of Nigeria.

The recommendations are tailored to address the cross-cutting challenges identified in the preceding section and to ensure that the tools effectively serve their intended purpose: enabling data-driven, inclusive, and coordinated decision-making for SSI development:

(1) **Develop an Integrated Data Infrastructure:** Design the mapping tool as a centralized data platform that consolidates all relevant information for irrigation planning – including geo-spatial layers on soil types, water resources (rivers, groundwater potential), weather/climate data, current irrigation sites, crop patterns, and socio-economic data (farmer locations, demographics). This should involve linking or integrating databases from

NiMet (climate), NIHSA (hydrology), agricultural surveys, and any remote sensing data available. The tool's architecture must accommodate real-time updates and ensure data quality control. Where data gaps exist (e.g., no recent surveys), the project should support targeted data collection (such as a national farmer registry or water point mapping exercise). Crucially, the platform should be open access (with appropriate user permissions) so that all stakeholders—government planners, banks, researchers, extension agents—can retrieve and use the information. Consider incorporating a feature for stakeholders to contribute data as well (crowdsourced inputs or periodic field updates via mobile apps).

(2) **Ensure User-Centric and Inclusive Tool Design:** Following HCD principles, the tool's design should be driven by the needs and contexts of its end-users—namely, the stakeholder groups involved in the workshops. Conduct follow-up co-creation sessions or user testing with government analysts, extension officers, bankers, and local suppliers to refine the interface and features. The tool should have different user modes or dashboards tailored for these groups. For example, a policy-maker dashboard might highlight macro-level maps of irrigation suitability, infrastructure overlays, and scenario analysis for planning. An extension agent view might allow one to zoom into a community to see water source proximity, recommended crop irrigation methods, and farmer lists, which they can use in field advisories. A banker or investor view could show risk maps (areas prone to drought/food), productivity indices, and existing irrigation project locations to inform lending or investment decisions. Importantly, design the tool to be accessible: use intuitive visualizations (color-coded maps, icons), local language options where possible, and compatibility with low-bandwidth environments (offline functionality or a lightweight mobile version) to account for rural internet limitations. Incorporate training modules or tooltips within the tool to educate users on interpreting the data. Also, integrate gender-responsive features—for instance, the ability to filter or display data by gender (if data available, such as highlighting regions with more female farmers, or indicating areas where women's access to irrigation is low). By making the tool easy to use and relevant to each stakeholder's decisions, we increase adoption.

(3) **Integrate Decision-Support Functions and Analytics:** Go beyond static maps—incorporate analytical tools and decision-support features within the platform. For instance, include a suitability analysis module where users can input criteria (soil type, water availability, farm size), and the tool highlights optimal areas for specific irrigation interventions (this could help government target investments or help banks identify viable zones for lending). Add a scenario planning feature: e.g., "If rainfall decreases due to climate change, which areas remain suitable for irrigation?" or "If a new dam is built at location Y, how many hectares become irrigable downstream?" Such forward-looking analytics will help policymakers and investors make informed decisions. For financial institutions, incorporate a risk assessment tool that uses the data (weather trends, yield data, maybe even satellite vegetation indices) to generate a simple risk score or profile for a given location or project.

Financial institutions could use this tool to evaluate loan applications, complementing credit histories with geospatial risk information. For equipment suppliers or extension programs, the tool could forecast demand hotspots – e.g., identifying communities with high suitability but low current irrigation, indicating latent demand. Additionally, ensure the tool can generate reports and visual outputs that can be printed or shared—such as PDF briefs with maps and key stats for a particular state or LGA—to support decision meetings or funding proposals.

(4) **Link the Tool with Key Socio-economic Variables**: For instance, leveraging the tools to catalyze innovative financing models. We recommend implementing a program that utilizes the tools outputs to steer a "challenge fund" or credit facility for SSI. For example, government or donors could establish a fund for banks that gives interest rebates or partial guarantees for loans issued in high-priority areas identified by the suitability mapping but currently underutilized. The tool can thus serve to verify and monitor such priority areas. Similarly, integrate the tool with any existing insurance platforms—if an index insurance scheme is being expanded, the tool's climate and yield data layers can feed into index design and verification (e.g., quickly identifying drought-affected zones via remote sensing). Encourage microfinance institutions and agri-tech startups to use the tools open data to develop farmer credit scoring or recommend locations for group lending schemes. For equipment suppliers, the project can share mapping insights so that they can plan inventory for regions likely to adopt irrigation (maybe even coordinate "last-mile dealer" expansion to those areas). Essentially, formalize partnerships where financial and private sector actors commit to using the tool in their operations in exchange for support, e.g., training on the tool, co-development of features, or policy incentives.

(5) **Implement a Phased Rollout and Iterative Improvement:** Plan the deployment of the mapping tool in phases. Start with a pilot phase (perhaps in one state or a couple of local government areas in different geo-zones, e.g., one in the north and one in the south) to test the tool in a real-world setting. During this phase, closely monitor usage, gather user feedback from various stakeholders, and measure initial outcomes (did extension agents change their plans? Did a bank make a loan decision influenced by the tool? Use this feedback to refine the tool's features, fix any data issues, and improve the user interface. Next, move to a scaling phase where the tool is rolled out to additional states or nationally, coupled with the capacity-building efforts mentioned. Ensure that the multi-stakeholder steering committee remains active in this phase to solve any inter-agency issues (like reluctance to share data or conflicts in usage). Also, secure commitments for ongoing maintenance—assign a dedicated technical team (perhaps at a research institute or within the ministry) to update the data layers and software. Establish protocols for continuous data updating (e.g., integrate an API with meteorological data for automatic updates). For sustainability, develop a business or sustainability plan for the tool: this could involve government budget allocation for its upkeep or revenue generation via premium services (although core data should

remain free). Plan for periodic impact assessments to show the tool's benefits, which will help justify continued funding. Additionally, consider aligning the tool with broader national initiatives (like Nigeria's agricultural transformation agendas or digital economy strategy) to institutionalize it.

By considering these recommendations, data, platforms and tools become not merely technological products but part of a broader solution ecosystem—one that aligns policy, finance, and community action towards scaling small-scale irrigation. The recommendations ensure that the tools are relevant ***(through user-centric design),*** reliable ***(through robust data integration)***, used ***(through training and stakeholder buy-in),*** and useful ***(through features that directly address decision-making needs).***

7. Conclusion

The synthesis of the HCD workshops in Kano, Oyo, and Abuja highlights a convergence of challenges and a shared vision for unlocking Nigeria's SSI potential. Stakeholders across government, finance, and the private sector have articulated not only their frustrations but also their readiness to innovate and collaborate in advancing SSI.

The findings show that technical solutions to address actor group concerns require stronger institutions, new funding modalities, skilled people, and inclusive policies to be effective. Encouragingly, the workshops generated a cohesive set of strategies—from establishing coordination platforms and data systems to creating new loan products and service networks—that together form a blueprint for action.

Implementing the recommendations from these engagements will require sustained commitment and partnerships. It calls for government agencies to break out of silos and work in concert, for financial institutions to embrace new models and share risk, and for private actors to invest in local capacity and inclusive outreach.

The proposed decision support tools are a catalytic piece in this puzzle: if developed and deployed in line with the user-driven insights, they can provide the common lens through which all stakeholders can plan, prioritize, and monitor SSI investments. The tools can foster transparency (by openly showing where needs and opportunities are), drive efficiency (by targeting resources to where they have the most impact), and promote learning (by tracking outcomes and facilitating feedback). In essence, it becomes a platform around which a community of practice in small-scale irrigation can coalesce.

As an example, a platform with geo-referenced data on irrigation potential, crop yields, and risks, can become a resource for banks and insurers to evaluate opportunities and design targeted products. Moreover, integrating finance considerations (like identifying high-potential areas for irrigation investment or mapping risk zones) can support both lenders and farmers, particularly if it serves to develop digital farmer profiles or risk maps.

The solutions suggested by the three actor groups underscore the importance of engaging not only policymakers and financial institutions, but also the private sector. For instance, mapping areas of high irrigation potential could help suppliers identify new markets (areas where demand for equipment might grow) and plan distribution logistics accordingly. Likewise, the tools could incorporate information on infrastructure and accessibility that suppliers need (like mapping road networks or distance to service centers).

The emphasis on after-sales service and extension suggests that the tool implementation should be accompanied by on-ground programs (training technicians, etc.) to truly make a difference in technology adoption. Ensuring the decision support is accessible and useful for entrepreneurs and local dealers—perhaps via a business-facing dashboard with market analytics—could be a consideration. Above all, the solutions around data, coordination, and user education echo across stakeholders, indicating that any tools should be part of a holistic approach that addresses these cross-cutting needs.

Nigeria stands to gain tremendously from scaling-up smallholder irrigation in terms of food security, climate resilience, and rural incomes. The HCD workshops have made it evident that the knowledge and creativity needed to surmount current barriers already exists among the country's practitioners and policymakers. What remains is to translate this collective wisdom into action. By following the integrated recommendations and keeping stakeholders engaged through the process, important steps toward accelerating SSI can be undertaken. In moving from pilots and plans to a nationally coordinated effort, Nigeria can move beyond fragmented efforts to an era of data-informed, inclusive, and sustainable irrigation growth. The journey will require iterative refinement and perseverance, but with the momentum built and a clear roadmap outlined, the foundation is set. Now, bold execution and cross-sector collaboration will be the keys to turning these insights into tangible, transformative outcomes for small-scale farmers and the nation's agricultural future.

References

Balana, B., Bizimana, J.C., Richardson, J.W., Lefore, N., Adimassu, Z., Brian K. Herbst, B.K. (2020). Economic and food security effects of small-scale irrigation technologies in northern Ghana, *Water Resources and Economics*, 29. 100141. https://doi.org/10.1016/j.wre.2019.03.001

Balana, B.B., Mekonnen, D., Haile, B., Hagos, F., Yimam, S., & Ringler, C. (2022). Demand and supply constraints of credit in smallholder farming: Evidence from Ethiopia and Tanzania, *World Development*, V.159. 106033. https://doi.org/10.1016/j.worlddev.2022.106033

Brown, T. & Wyatt, J. (2010). Design Thinking for Social Innovation. *Stanford Social Innovation Review*. *https://ssir.org/articles/entry/design_thinking_for_social_innovation*

Bryan, E., Hagos, F., Mekonnen D. K., & Yimam, S. (2020). "The diffusion of small-scale irrigation technologies in Ethiopia: stakeholder analysis using Net-Map," IFPRI Discussion Paper No. 1950. Washington DC: IFPRI.

Clayton, S., (2012). Will People Act to Mitigate Climate Change? *Analyses of Social Issues and Public Policy*, 12(1): 221-224.

Durga, N., Schmitter, P., Ringler, C., Mishra, S., Magombeyi, M.S., Ofosu, A., Pavelic, P., Hagos, H., Melaku, D., Verma, S., Minh, T., Matambo, C., (2-24). Barriers to the uptake of solar-powered irrigation by smallholder farmers in Sub-Saharan Africa: A review, *Energy Strategy Reviews. V.51*. 101294, https://doi.org/10.1016/j.esr.2024.101294

Enhancing Financial Innovation and Access (EFInA) (2020). Access to Financial Services in Nigeria 2020 Survey. Abuja, Nigeria. https://efina.org.ng/wp-content/uploads/2022/02/State-of-Womens-Financial-Inclusion-2020.pdf

Federal Ministry of Agriculture and Rural Development (FMARD). (2016). The Agriculture Promotion Policy (2016 – 2020) Building on the Successes of the ATA, Closing Key Gaps – Policy and Strategy Document. Abuja, Nigeria. https://nssp.ifpri.info/files/2017/12/2016-Nigeria-Agric-Sector-Policy-Roadmap_June-15-2016_Final.pdf

Federal Ministry of Agriculture and Rural Development (FMARD). (2022). The National Agricultural Transformation and Innovation Policy (NATIP 2022-2028). Abuja, Nigeria. https://agriculture.gov.ng/wp-content/uploads/2024/06/National-Agricultural-Technology-and-Innovation-Policy-NATIP-2022-2027.pdf

Fernald, A., Guldan, S., Boykin, K., Cibils, A., Gonzales, M., Hurd, B., Lopez, S., Ochoa, C., Rivera, J., Rodrigues, S., Steele, C., 2015. Linked hydrologic and social systems that support resilience of traditional irrigation communities. *Hydrol. Earth Syst. Sci.* 19 (1), 293–307. https://doi.org/10.5194/hess-19-293-2015.

IDEO (2015). The Field Guide to Human-Centered Design – Design Toolkit. *https://www.ideo.com/journal/design-kit-the-human-centered-design-toolkit*

Burney, J.A., & Naylor, R.L., (2012). Smallholder Irrigation as a Poverty Alleviation Tool in Sub-Saharan Africa, *World Development*, 40(1):110-123.

Lam, W.F. (2006). Foundations of a robust social-ecological system: irrigation institutions in Taiwan. *Journal of Institutional Economics*, 2: 2, 203–226.

Mekonnen, D., J. Choufani, E. Bryan, B. Haile and C. Ringler. 2022. Irrigation improves weight-for-height z-scores of children under five, and women's and household dietary diversity scores in Ethiopia and Tanzania. Maternal and Child Nutrition. 18(4): e13395. https://doi.org/10.1111/mcn.13395.

Meneyahel Z. T., Balana, B. B. & Bizimana, J.C. (2021). Assessment of smallholder farmers' demand for and adoption constraints to small-scale irrigation technologies: Evidence from Ethiopia. *Agricultural Water Management,* vol. 250(C). 106855. https://doi.org/10.1016/j.agwat.2021.106855.

Minh, T., Cofie, O., Lefore, N., & Schmitter, P. (2020). Multi-stakeholder dialogue space on farmer-led irrigation development in Ghana: an instrument driving systemic change with private sector initiatives. Knowledge Management for Development Journal, 15(2) 98-118.

Ogunjimi, L.A.O., & Adekalu, K. O. (2002). Problems and constraints of small-scale irrigation (Fadama) in Nigeria. *Food Reviews International*, *18*(4), 295–304. https://doi.org/10.1081/FRI-120016207

Passarelli, S., Mekonnen, D., Bryan, E. *et al.* Evaluating the pathways from small-scale irrigation to dietary diversity: evidence from Ethiopia and Tanzania. *Food Sec.* 10, 981–997 (2018). https://doi.org/10.1007/s12571-018-0812-5

Takeshima, H. (2016). Understanding irrigation system diversity in Nigeria: a modified cluster analysis approach. Irrigation and Drainage 65: 601-612, https://doi.org/10.1002/ird.1973

Theis, S., Lefore, N., & Meinzen-Dick, R. et al. (2018). What happens after technology adoption? Gendered aspects of small-scale irrigation technologies in Ethiopia, Ghana, and Tanzania. *Agric Hum Values* 35: 671–684. https://doi.org/10.1007/s10460-018-9862-8

Wiggins, S., & Lankford, B. (2019). *Farmer-led irrigation in Sub-Saharan Africa: synthesis of current understandings. Synthesis Report of the DFID-ESRC Growth Research Programme.* https://odi.org/en/publications/farmer-led-irrigation-in-sub-saharan-africa-synthesis-of-current-understandings/

Woodhouse, P., Veldwisch, G. J., Venot, J. P., Brockington, D., Komakech, H., & Manjichi, Â. (2016). African farmer-led irrigation development: re-framing agricultural policy and investment? *The Journal of Peasant Studies*, *44*(1), 213–233. https://doi.org/10.1080/03066150.2016.1219719

Xie, H., L. You, & Takeshima, H. (2017). Invest in small-scale irrigated agriculture: A national assessment on potential to expand small-scale irrigation in Nigeria. *Agricultural Water Management* 193: 251-264. https://doi.org/10.1016/j.agwat.2017.08.020

Xie, H., Perez, N., Anderson, W., Ringler, C., & You, L. (2018). Can Sub-Saharan Africa feed itself? The role of irrigation development in the region's drylands for food security. *Water International*, *43*(6), 796–814. https://doi.org/10.1080/02508060.2018.1516080

Xie, H., You, L., Wielgosz, B. & Ringler, C. (2014). Estimating the potential for expanding smallholder irrigation in Sub-Saharan Africa. *Agricultural Water Management*. 131(1): 183–193. https://doi.org/10.1016/j.agwat.2013.08.011

You, L, Ringler, C., Wood-Sichra, U., Robertson, R., S. Wood, S., Zhu, T., Nelson, G., Guo, Z., Sun,Y. (2011). What is the irrigation potential for Africa? A combined biophysical and socioeconomic approach. *Food Policy*, 36(6). 770-782.

Annexes

Annex I. Discussion Guides for HCD workshops

This document provides an initial set of questions to guide the HCD workshops with the three intermediary user groups of the project – *Government, Irrigation equipment Distributors, and Financial Institutions.* As highlighted in the project proposal, we will conduct a series of HCD workshops in two distinct rounds. In the first round of workshops, we will be focusing on the first three steps of the HCD process (i.e., ***Empathize, Define, and Ideate***) where the focus will be on understanding the problems (what the users want/demand/need etc. and receiving suggested solutions/ideas to solve the problems from their perspectives. The set of questions listed in this document are for the first round of the HCD process.

Note: The questions are just to guide the discussion. They are neither exhaustive nor placed in strict sequential order, rather during the workshops various issues linked to the SSI scaling can be brought through follow-up probing questions, etc.

Section A. Discussion Guide for Government Representatives

This guide is designed to generate deep and actionable insights from government representatives, ensuring a thorough understanding of their challenges, perspectives, and needs in scaling small-scale irrigation.

1. Landscape Policy and Support for Irrigation

- What are the key policies or initiatives currently in place to support small-scale irrigation (SSI) in your region?
- How effectively are these policies being implemented at the local level?
- Are there specific policies or regulations that have facilitated or hindered small scale irrigation expansion?
- If you had the power to modify one aspect of small-scale irrigation policy, what would it be and why?

2. Water Availability and Access for Farmers

- Under the current policies, do farmers receive sufficient water for irrigation throughout the year?
- Are there seasonal shortages or regional disparities in water access?
- What measures are in place to ensure water is distributed equitably among different farming communities?
- How do small-scale farmers access water permits, and are there barriers that prevent them from obtaining necessary approvals?

3. Impact of Climate Change on Water Resources

- How have you observed climate change impacting water availability for agriculture in recent years?
- Are there specific weather patterns or extreme events (droughts, floods) that have disrupted small scale irrigation planning?
- What adaptation strategies has your agency considered or implemented to mitigate these climate-related challenges?

- Do you have access to climate forecasts or early warning systems for water management? If not, what information would be most useful?

4. Data and Decision-Making for SSI

- What tools, maps, or datasets do you currently rely on for decision-making regarding small scale irrigation investments?
- How frequently is this data updated, and is it accurate enough for planning purposes?
- Are there any significant data gaps that limit effective decision-making?
- What additional environmental, hydrological, or social data would improve your ability to prioritize irrigation projects?

5. Financing SSI

- What are the main sources of financing SSI in your region?
- Is there any government initiatives enabling small scale irrigation to access finance?
- What enabling environment and strategies could improve access to finance to SSI?

6. Collaboration and Stakeholder Engagement

- Which other organizations or agencies do you collaborate with on small scale irrigation initiatives?
- What challenges do you face when coordinating with other stakeholders, such as finance institutions or irrigation equipment suppliers?
- Are there existing platforms or working groups where irrigation-related issues are discussed? If not, would such a forum be beneficial?

7. Gender and Social Inclusion in Irrigation Policies

- How does the government ensure that small scale irrigation policies are gender-responsive and inclusive?
- What specific challenges that women or marginalized communities face in accessing SSI?
- What programs or incentives exist to support female-led farming initiatives?
- How can policies be improved to promote more equitable access to small scale irrigation resources?

8. Practical Implementation Challenges

- What are the bottlenecks for scaling small scale irrigation in Kano?
- Is there any government initiatives to increase small scale irrigation?
- Have you encountered resistance or adoption challenges from farmers regarding new small scale irrigation technologies?

9. Future Outlook and Recommendations

- What do you see as the biggest opportunity for scaling small-scale irrigation in your region?
- Are there any upcoming policy changes or investments that could impact small scale irrigation expansion?
- If you could implement one high-impact solution for improving small scale irrigation systems, what would it be?

Section B. Discussion Guide Irrigation Equipment Distributors

This guide is designed to extract deep insights from irrigation equipment distributors, allowing for a more user-centered approach to decision-support tool and solution development. The questions are structured to cover critical aspects of scaling small-scale irrigation, which include business challenges, data needs, financing, market barriers, and future opportunities.

1. Business Model and Market Reach

- What types of irrigation technologies do you currently offer in Nigeria?
- Who are your primary customers?
- What percentage of Nigeria's smallholder farmers do you estimate are currently using your products?
- What are the major regions in Nigeria where your products are in high demand, and why?
- How do you determine pricing, and what factors influence cost fluctuations in Nigeria?
- Do you have partnerships with government programs, NGOs, or international donors to support irrigation expansion?
- What factors influence your product selection for different regions?

2. Market Barriers and Expansion Challenges

- What are the biggest barriers to expanding access to small-scale producers?
- What supply chain constraints do you face in sourcing, storing, and distributing small scale irrigation equipment?
- Are there policies or regulatory challenges that affect your ability to expand your market?

3. Decision-Making and Customer Insights

- How do you decide which Nigerian states or regions to market and distribute your products?
- What factors influence your decisions about stocking certain irrigation technologies?
- What specific information about smallholder farmers' needs would help you improve product availability and outreach?
- How do you assess demand in different regions of Nigeria?
- Do you collect feedback from customers about their experiences with your products? If so, how is this data used?
- Do you see differences in adoption rates between male and female farmers? If so, what are the key factors?
- Have you observed cultural or social factors that influence small scale irrigation technology adoption in Nigeria?

4. Use of Digital Tools and Data Do you use digital tools or platforms to analyze market trends and demand small scale irrigation technologies?

- If so, what kind of digital platforms or data sources do you currently rely on to make business decisions?
- Would a digital tool that maps high-potential irrigation areas help you expand your market? What features would be most useful?
- What information would be most useful in deciding where and how to scale your services?

5. Financing and Business Support Needs

- What financing models (e.g., loans, leasing, pay-as-you-go) do you currently offer to farmers, if any?
- What are the biggest challenges Nigerian farmers face in accessing financing for small scale irrigation equipment?
- Are there government subsidies or credit schemes that support smallholder farmers in purchasing small scale irrigation tools?
- Would financial tools (e.g., credit scoring for smallholders, repayment tracking) help you expand access to more customers?
- Do you collaborate with financial institutions to help farmers access small scale irrigation loans? If not, what challenges prevent this collaboration?
- Would a tool that connects farmers with financing options improve adoption rates for your products?
- Have you noticed differences in how men and women access financing for irrigation equipment in Nigeria?

6. Adoption, Training, and Capacity Building

- Do you currently provide any training programs for farmers? If so, what has been the impact?
- In your view, do you think training could enhance adoption small scale irrigation?
- In your view, what training or capacity-building initiatives would make it easier for you to adopt new technologies or expand your business?
- Would you prefer to sell or lease small-scale irrigation equipment, and why?
- How important is after-sales support or maintenance services in your business model?
- Would a digital tool for customer support, troubleshooting, or maintenance tracking be beneficial to you and the farmers?

7. Future Outlook and Recommendations

- What do you see as the biggest opportunity for scaling small-scale irrigation in Nigeria?
- What role should the private sector irrigation equipment distributors play in scaling small scale irrigation?
- Are there any specific government policies or support mechanisms that would help your business grow?
- If you could change one thing about the small-scale irrigation landscape, what would it be?
- What partnerships or innovations would help you better serve smallholder farmers?

Section C. Discussion Guide for Financial Institutions

This guide is designed to explore the perspectives, challenges, and needs of financial institutions in supporting small-scale irrigation (SSI) expansion in Nigeria. It focuses on critical factors aiming at improving financial access for farmers and irrigation businesses, which include credit assessment, risk management, gender-inclusive financing, and the role of digital tools.

1. Financing Irrigation: Current Practices and Policies

- What financial products do you currently offer for agricultural investments, particularly for small-scale irrigation (SSI)?
- What percentage of your agricultural loan portfolio is directed toward small scale irrigation?
- What are the eligibility criteria for farmers or businesses seeking small scale irrigation financing?
- Do you offer specialized financing packages for irrigation distributors, cooperatives, or farmer groups?
- How do you determine the loan repayment structure for farmers investing in small scale irrigation technologies?
- Have you partnered with government programs, development banks, or donor agencies to financing small scale irrigation?
- Do you provide low-interest loans, subsidies, or alternative financing models for smallholder farmers?

2. Risk Assessment and Challenges in Financing Irrigation

- What are the most common risks associated with small scale irrigation financing?
- How do you assess the creditworthiness of smallholder farmers who may lack collateral or financial history?
- What measures do you take to mitigate financial risks associated with irrigation investments?
- What role does climate risk and water availability play in your financing decisions for irrigation projects?
- What are the key barriers preventing financial institutions from providing finance to SSI??

3. Use of Data and Digital Tools in Financing Decisions

- What data sources do you currently use to evaluate small scale irrigation loan applications?
- Would a tool that provides real-time climate, soil, or water resource data improve your ability to finance irrigation projects?
- How would a risk assessment tool that evaluates the financial and environmental sustainability of small-scale irrigation projects benefit your institution?
- Would a digital mapping tool identifying high-potential small scale irrigation areas help you prioritize investments?
- Do you currently use mobile banking, fintech, or blockchain-based solutions for agricultural financing?
- How can digital tools improve loan disbursement, monitoring, and repayment tracking for irrigation projects?
- Are you open to exploring new financial technologies (e.g., AI-driven credit scoring, remote sensing for risk assessment) to improve access to small scale irrigation financing?

4. Gender-Inclusive Financing for Irrigation

- Have you observed any gender-specific constraints in accessing small scale irrigation financing?
- Do female and male farmers have equal access to small scale irrigation loans? If not, why?
- Do you have dedicated financial products tailored for women farmers or women-led agribusinesses?
- Would a tool that identifies gender-disaggregated financial trends in small scale irrigation investments be useful?
- What measures can financial institutions take to make small scale irrigation financing more accessible to women? (e.g., flexible collateral requirements, lower interest rates, group-based lending models)
- How do cultural or social factors impact women's access to financing in Nigeria's agricultural sector?

5. Opportunities for Scaling Irrigation Financing

- What are the main gaps in current financial products for small scale irrigation?
- How can government policies, subsidies, or public-private partnerships improve small scale irrigation financing?
- Would your institution benefit from a shared database or digital registry that tracks small scale irrigation loans, repayment trends, and farmer credit history?
- What incentives or risk-sharing mechanisms would encourage banks to invest more in small scale irrigation financing?
- How could a small-scale irrigation financing toolkit help bridge information gaps and streamline investment decisions?
- Are there opportunities to develop insurance-backed financing that protects against climate risks affecting small scale irrigation investments?
- What recommendations do you have for strengthening financial access for scaling small-scale irrigation?

Final Thoughts and Next Steps

- If you could change one key challenge in financing small scale irrigation, what would it be?
- What role should financial institutions play in scaling small scale irrigation financing?

Annex II. Summary of Top three Challenges/ Issues per Intermediary Actor

Intermediary Group	Priority Issue / Challenge	Brief Elaboration	Key Data Needs to Address this Challenge
Government / Policy Makers	Fragmented policies & weak inter-agency coordination	Responsibilities for water and irrigation management span multiple ministries and levels of government, leading to overlapping mandates and inconsistent policies. This fragmentation hinders coherent planning and slows down investment decisions.	• List of current policies, mandates, and institutional responsibilities (federal, state, local) • Geospatial data on ongoing and planned irrigation projects • Stakeholder network maps to identify decision nodes and coordination gaps
	Inadequate funding & limited extension capacity	Public budgets for irrigation and extension services are small and often misallocated. Extension agents lack the resources and training needed to support farmer-led irrigation, limiting uptake of new technologies.	• Historical and current budget allocations for irrigation, extension, and agricultural subsidies • Number and distribution of extension agents, their training status, and workload • Access to credit, supply and demand side constraints to agricultural finance
	Data gaps & weak information systems	Reliable high resolution hydrological, meteorological, socio-economic, and agricultural data are scarce. Policy makers therefore struggle to plan for floods, droughts, and irrigation expansion.	• Local hydro-meteorological datasets (rainfall, river flows, groundwater levels) • Soil and crop suitability maps • Cost and benefit data for different irrigation technologies to inform resource prioritization • Real-time remote-sensing data (e.g., vegetation indices) to feed early-warning systems and decision dashboards • Small-scale irrigation suitability maps
Financial Institutions	Perceived high default risk & irregular farm incomes	Lenders view smallholder farmers as risky borrowers due to volatile yields, climate shocks, and irregular incomes. As a result, credit for irrigation investments is either unavailable or comes at prohibitively high interest rates.	• Historical yield and price data for irrigated vs. rain-fed crops • Weather and climate risk profiles for key production areas • Farmer income and expenditure patterns to model repayment capacity
	Stringent collateral requirements & limited assets	Many farmers do not hold land titles or other acceptable collateral, and women often lack property rights altogether. This makes it hard to qualify for conventional loans.	• Land tenure records and asset ownership data by gender • Information on existing credit guarantee schemes or group lending arrangements • Legal and regulatory frameworks governing movable collateral (e.g., equipment)
	Low awareness & demand for irrigation credit	Farmers often lack information on the returns to irrigation and are unfamiliar with available finance products. Banks likewise have limited knowledge about irrigation's risk-reducing benefits, so they underinvest in product development.	• Data on farmer awareness of irrigation technologies and financing options • Bank data on agricultural loan portfolios and uptake rates • Market studies detailing profitability of small-scale irrigation under different technologies
Irrigation Equipment Dealers	Import barriers, high equipment costs & limited local production	Modern irrigation systems (drip kits, solar pumps) are imported and expensive, making them inaccessible to most smallholders. Tariffs, currency volatility, and weak local manufacturing keep prices high and deter investment.	• Import tariff schedules, VAT rates, and other taxes applied to irrigation equipment • Price data for imported vs. locally manufactured pumps and kits • Exchange rate history and its pass-through to equipment prices

Intermediary Group	Priority Issue / Challenge	Brief Elaboration	Key Data Needs to Address this Challenge
	Limited access to finance & distribution networks	Small and medium-sized dealers struggle to obtain working capital to import or stock equipment. They often lack reliable distribution channels or trained technicians, limiting reach beyond urban centers.	• Dealer balance sheet data and loan eligibility requirements • Maps of dealer and service-center locations • Demand forecasts by region to inform inventory planning and potential financing needs
	Low farmer adoption & awareness of modern technologies	Many farmers are unfamiliar with drip irrigation, solar pumps, and other modern systems; when they do adopt them, misuse or underutilization is common. Weak after-sales service and limited demonstration sites contribute to skepticism.	• Data on farmer preferences, knowledge, and adoption rates of various irrigation technologies • Field-level performance data (yields, water savings) for modern vs. traditional systems • Records of training events, demo plots, and after-sales service requests to identify information gaps • Location of repair services