The exposure-based pathway to scaling best-fit bundles of irrigation technologies, services and practices in Koutiala, Mali

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Produced by: [1]International Water Management Institute

Published by: International Institute of Tropical Agriculture

July 2022

www.africa-rising.net

The Africa Research In Sustainable Intensification for the Next Generation (Africa RISING) program comprises three research-in-development projects supported by the United States Agency for International Development (USAID) as part of the U.S. Government's Feed the Future initiative.

Through action research and development partnerships, Africa RISING is creating opportunities for smallholder farm households to move out of hunger and poverty through sustainably intensified farming systems that improve food, nutrition and income security, particularly for women and children, and conserve or enhance the natural resource base.

The three regional projects are led by the International Institute of Tropical Agriculture (in West Africa and East and Southern Africa) and the International Livestock Research Institute (in the Ethiopian Highlands). The International Food Policy Research Institute leads the program's monitoring, evaluation and impact assessment.

Africa RISING appreciates the support from the American people delivered through the USAID Feed the Future initiative. We also thank farmers and local partners at all sites for their contributions to the program.

Acknowledgments

This work is funded by Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) through the United States Agency for International Development (USAID), under Agreement No. AID-BFS-G-11-00002. The work was also co-funded by the Feed the Future Innovation Lab for Small-Scale Irrigation (ILSSI) through USAID, under the terms of Agreement No. AID-OAA-A-13-00055, and the CGIAR Research Program on Water, Land, and Ecosystems (WLE).

Contents

List of abbreviations

AMASSA	Association Maliene pour la Sécurité et la Souverainité alimentaire
AMEDD	Malian Association for Awakening to Sustainable Development
APCAM	Assemblée Permanente des Chambres d'Agriculture du Mali
BNDA	Banque Nationale de Développement Agricole
ETCOM	Entreprise de Construction du Mali
NGO	Non Gouvernemental Organization
PDSU Koutiala	Programme de Développement Economique Local et de Sécurité Alimentaire de
SNDI	National Strategy for Irrigation Development

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Summary

This study was conducted in Africa Rising sites in Koutiala, Mali, to investigate existing irrigation technologies and practices and to inform scaling pathways along the irrigated vegetable value chain (IVVC). Using action research, the study attempted to understand the landscape of irrigation technologies, practices and services based on this value chain. The aim was to identify the best-fit scaling pathways and the conditions under which these pathways could lead to better development outcomes. The IVVC in Koutiala consists of dry season production and marketing at local weekly and daily urban markets. Throughout the chain, there are three main challenges: water is scarce, the initial investment costs of irrigation technologies are high, and limited access to markets for vegetable products. Four segments of farmers are involved in vegetable production in Koutiala. Resource-rich farmers can buy high-end irrigation technology and hire labor without external support. Resource-limited farmers can partially afford some equipment, such as fuel-powered motorized pumps, but they still need other equipment, which can take time for them to acquire. Resource-poor farmers are the segment of farmers who practice manual irrigation, including drawing water from wells and using watering cans and buckets to water their plots. Finally, Farmer cooperatives are composed of resource-poor women and men farmers who have become overreliant on external support from nongovernmental (NGOs) and research organizations for such services as maintenance and repair of irrigation equipment.

Against this background, the study identified a set of best-fit bundles of irrigation technologies, practices and services for scaling pathways. These consist of the most available and inexpensive second-hand materials for farmers, combined with expensive equipment provided by external support. This may not only reduce the initial investment costs for both farmers and support organizations, but it could also encourage farmers to take greater initiative and be more willing to invest on their own. Furthermore, the scaling pathway could also increase the outreach of this hybrid of irrigation technologies, practices and services by tailoring them to the specific segments of farmers such as resource-rich, resource-limited and resource-poor farmers and farmer groups. Although different factories, technicians and service providers together could help scale this pathway in Koutiala, the dominant project mindset could constrain the initial step. This mindset tends to deter farmers from making efforts to explore existing opportunities, including credit from financial organizations. Instead, they expect support organizations to provide these opportunities for free. The unsustainability of such reliance is what motivates the scaling pathway explored in this report.

1. Introduction

Several studies have identified access to water as an adaptation pathway to address the increased vulnerability of communities and agriculture systems to climate-related shocks and stressors (Smith and Matthews 2019). Rainfed agriculture and the evolving changes and uncertainties in the rainfall pattern, especially in Sahel countries, including Mali, make water the main driver that will define the future of agriculture and food security in these regions. In this regard, in 1999, the Malian government adopted its National Strategy for Irrigation Development (SNDI), the main framework for implementing irrigation programs and actions. The SNDI considered irrigation one of the most effective means of ensuring food security and nutrition, reducing imports, increasing rural incomes and limiting emigration from rural areas (Direction Nationale du Génie Rural 2016).

Investment in small-scale irrigation not only improves household consumption and production, and thus nutrition, but it also increases assets and incomes. More importantly, driven by increased production and household consumption, irrigation investment induces households to save more and share more within their villages, a form of informal social insurance investment. Therefore, irrigation investments offer "spillover gains," for households and communities outside of the requisite productivity gains (Dillon 2011).

In Mali, the return on investment of irrigation systems varies; for example, rice yields usually lie between 4 and 6 tons with full water control, while free flooding does not yield more than 1 ton and controlled flooding stands between 1 and 2 tons (Malabo Montpellier Panel 2018). Although rice remains the main irrigated crop under large-scale state-funded irrigation schemes, small-scale, farmer-led irrigation, including vegetables, is gaining importance in the irrigation policy process. In 2017, the Government of Mali passed a law that allocates a minimum of 15% of irrigated lands to women and youth under government irrigation land development programs.[1]

Yet, despite these increased government investments and initiatives in expanding land under irrigation, to date, only a small share of the country's land potential has been tapped (Malabo Montpellier Panel 2018). Although Mali's irrigated vegetable value chain (IVVC) is expanding, it is still mostly made up of rudimentary irrigation practices based on wells and hand-watering using buckets and cans. Irrigation equipment, including fuel pumps, solar panels, and pumps, is predominantly imported from China and sold at local markets by small and medium businesses. New technologies, such as gasoline-fueled and solar pumps, are gradually gaining ground, but the initial investment costs remain expensive for the average farmer. These high costs, combined with the widespread perception among stakeholders that "second-hand solar panels are better than new ones", make adopting irrigation for vegetable production messy and uncharted terrain that needs further investigation.

There is no linear process for finding the best-fit scaling approach for irrigation solutions in Malian agriculture. On this point, there is consensus. So instead of using a linear approach, this study adopts a systemic one to scale irrigation solutions (Minh et al. 2021). In this regard, it is necessary to understand the challenges, opportunities and conditions specific to Mali for scalable packages and scaling pathways for irrigation technologies, practices and services along the IVVC. However, the highly contextual nature of such an understanding requires a close look at each case. That is what motivated this study in Koutiala.

[1] One. YES! Malian women make progress in fight for land rights. Accessed May 16, 2022, 2018. https://www.one.org/international/blog/malian-women-fight-for-land-rights/

This study investigated technologies, practices and services based on the IVVC. The aim was to analyze the best-fit scaling pathways and the conditions under which these pathways could lead to better development outcomes. The following are the study's objectives:

- Investigate the existing irrigation technologies, practices, and services and the interest and willingness of farmers to adopt them.
- Understand the structure and function of the IVVC in the study area.
- Investigate irrigation supply and output markets.
- Characterize the enabling environment at local and district levels.
- Identify scalable bundles and pathways for scaling irrigation technologies, practices and services along the chain in Koutiala.

2. Analytical framework

In the study, we define the scalable bundle of irrigation technologies, practices and services as a complementary package that best fits within the study context and farmers' purchasing power, with the potential for larger impact and systemic transformation at scale. The value chain-based scaling pathway refers to a process of designing and implementing a set of strategies and corresponding activities so that farmers can invest in irrigated farming and commercialize their investment by engaging in the value chain. As such, each pathway can have at least one strategy, aiming to 1) address constraints that deter actors from engaging in the chain's performance and therefore benefitting from it, 2) create or strengthen links between and among the chain's actors and functions, and 3) improve the flow of knowledge, resources and products, and the distribution of added value. Some examples include improving business links and partnerships, providing better services, strengthening the chain's governance structure and improving policies and business environments. Figure 1 illustrates an analytical framework to identify value chain-based pathways for scaling irrigation technologies and water solutions with farmers and other actors in IVVCs.

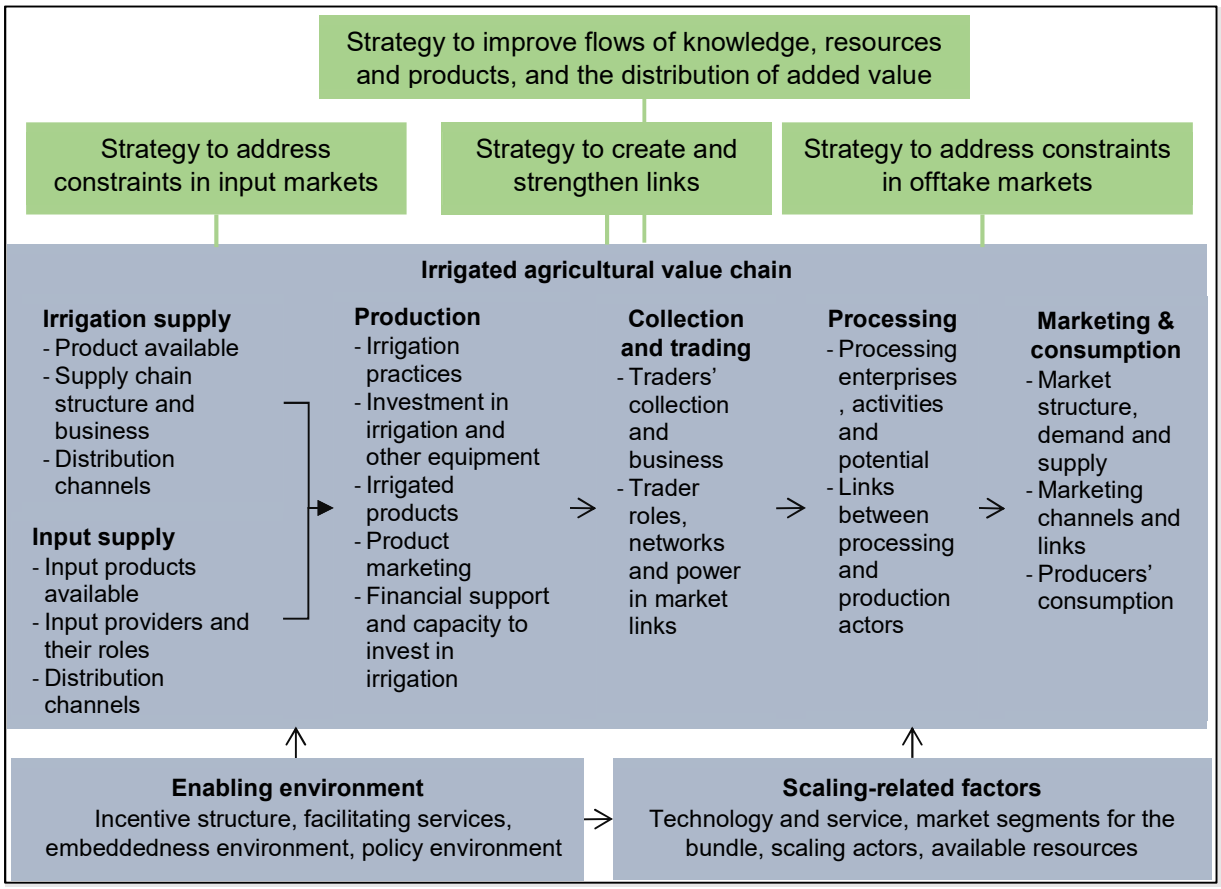
The center of the analysis is the local irrigation and farming system actors, and their relations and interactions with the different layers of the environment where scaling the bundles is embedded. The reason for this is that the farming system in the area is rainfed. For the dry season, this means that it is necessary to have irrigated water available to continue producing vegetables. Consequently, understanding the potential and scalability of irrigation-related innovation bundles for the actors requires identifying relationships with local actors, farmers, cooperatives and financial partners in the irrigation and farming system, cropping system, types of irrigation, and constraints and opportunities for the actors.

We used a value chain analysis to understand the overall context of irrigated products and the layers of production factors to improve sustainable production, markets and the entire value chain structure (Herman and Minh 2021). The layers include the overall irrigated agriculture value chain, the social and biophysical environment in which it is embedded, and the policy and institutional environments. These environments' constitutive elements and interplay were analyzed for insights into irrigated value chain-based scaling pathways.

The irrigated agricultural value chain includes inputs and irrigation suppliers, practices and supply chain, as well as farmer investments, the roles of co-ops and financial partners, relationships within the chain, and insight into constraints and opportunities. The enabling environment includes the social context, household dynamics and socioeconomics, access to land for different social groups, and the policy and institutional environments, such as sets of policies and regulations (Minh et al. 2021). The scaling

environment includes public support and interventions, private sector services and support for other practitioners that can help scale irrigation and water management solutions.

FIGURE 1. Framework to analyze the irrigated agricultural value chain for co-identifying scaling pathway.



Source: Author's elaboration.

3. Methodology: Action research approach

Research process

The methodology of an action-oriented research approach includes identifying, engaging and reflecting (Minh and Schmitter 2020). This approach has been contextualized and applied to scaling small-scale irrigation technologies, practices and services in the context of the Africa Rising project in Koutiala.

The ***co-identifying*** aimed at investigating the demand-supply link scaling pathway. First, the pathway was conceptualized. Then actors and stakeholders were connected who were considered the best combination to facilitate the supply of the scaling package and to link irrigators with input and output markets in the IVVC in Koutiala. This involved interactions with the best-fit actors identified from the analysis step.

The ***engaging*** aimed at bringing stakeholders together to discuss and understand their concerns, and to pave the way to share and deliver on expectations. To this end, a one-day workshop was organized in Koutiala to bring together different stakeholders, including government agencies, NGOs, private service providers, input suppliers, irrigation equipment and borehole drillers, and financial organizations. The workshop had three main parts to it: (1) identify the objectives for scaling irrigation technologies,

practices and services, (2) discuss with stakeholders the challenges related to the scaling, and (3) explore possible avenues for a win-win partnership between stakeholders for such scaling led by small producers. The workshop was also followed by individual interviews with relevant participants to deepen the discussions on issues specific to stakeholder domains and to describe the scalable bundles and scaling pathway.

The ***reflecting*** aimed at crosschecking, triangulating and making sense of information from every source, as well as reflecting the bundles and value chain-based pathways identified in the two previous steps with their reliability and feasibility. This step included a literature review combined with stakeholder engagement at both district and local levels to share knowledge and collectively solve problems associated with scaling irrigation solutions.

Data collection

Throughout the action research process, qualitative data on the irrigated agricultural value chain and enabling environment for the type of scaling in this study was collected in Africa Rising sites in Koutiala, as shown in Table 1.

TABLE 1**.** Overview of data from Africa Rising sites in Koutiala.

Method	Location	Topic/data
Farmer group interview		
Group interview with 5 male farmers	Cooperative/ Nampossela	- Information about the farmer-based organization (history and development, members and membership, organizational and governance structures, business services and development perspectives, support for irrigation) - Cooperation with other stakeholders
Group interview with 14 participants (6 women, 8 men)	N'Golonianasso	
Group interview with 12 farmers (4 women, 8 men)	Cooperative Ounaena Sirakele	
Group interview with 13 male farmers	Cooperative Benkadi Oueoutiè Zanzoni	
Group interview with 21 farmers (3 women, 18 men)	Cooperative Jiguisèmè M'Pessoba	
Multistakeholder consultation workshop		
17 participants (5 women, 12 men)	Koutiala City	- Discussions with stakeholders about the challenges related to spreading technologies, practices and services for small-scale irrigation - Exploring possible avenues for a win-win partnership between actors in which small-scale farmers
Individual interviews with other irrigated vegetable value chain actors and organizations		
Government agencies: - Regional Directorate of Agriculture - Regional Directorate of Rural Engineering - Regional Directorate of Hydraulics	Koutiala City Office Directorate of Agriculture	- Challenges to adopting irrigation technology - Government's policies and support for irrigation - Collaboration with farmers and other stakeholders - Regulations for borehole drilling - Biophysical characteristics and suitability of Koutiala soils for borehole drilling - Conditions for the eligibility of communities
Financial institutions: - Miniankala Kafo (intercommunal financial intermediation organization) - Soro Yiriwa (micro-credit organization)	Koutiala City	- Conditions for farmer access - Information on financial intermediation and support organizations - Farmer credit access for irrigation equipment - Relationship between microfinance organizations and farmers

Private sector actors: - Zamoho (private service provider) - Arc-en-ciel (input dealer) - ETCOM (borehole company, field technician provider, irrigation equipment dealer)	Koutiala City	- Typology of services and conditions - Typology of farmers and collaboration - Supply of inputs and irrigation equipment (origin, trade conditions, after-sales services) - Borehole services Challenges and opportunities for irrigation-related businesses
Individual interviews		
19 individual farmers	M'Pessoba, Nampossela, N'Golonianasso, Sirakele, and Zanzoni	- Cropping system, field size, types of crops - Irrigation practices and challenges and access to technologies - Access to extension services and credit - Marketing channels - Relationships with the cooperative

Source: Author's elaboration.

Data was collected in Koutiala City and the villages of NGolonianassso, Nampossele, Sirakele, Zanzoni and M'Pessoba. It involved seven focus group interviews with farmers and 28 individual semi-structured interviews with farmers in various locations and other actors in the IVVC.

Individual and group interviews were held in each location with male and female farmer irrigators. In all the villages, participants were members of Africa Rising activities. The group associated with Africa Rising is part of a bigger village cotton cooperative. Apart from N'Golonianasso, where the group works in Africa Rising's technological park, all the activities are individual. Individual interviews were held with every category of stakeholders. These included irrigation support government organizations, financial organizations, input dealers, irrigation equipment traders, equipment installation and repair technicians, borehole drillers, services providers and development project staff.

Data analysis

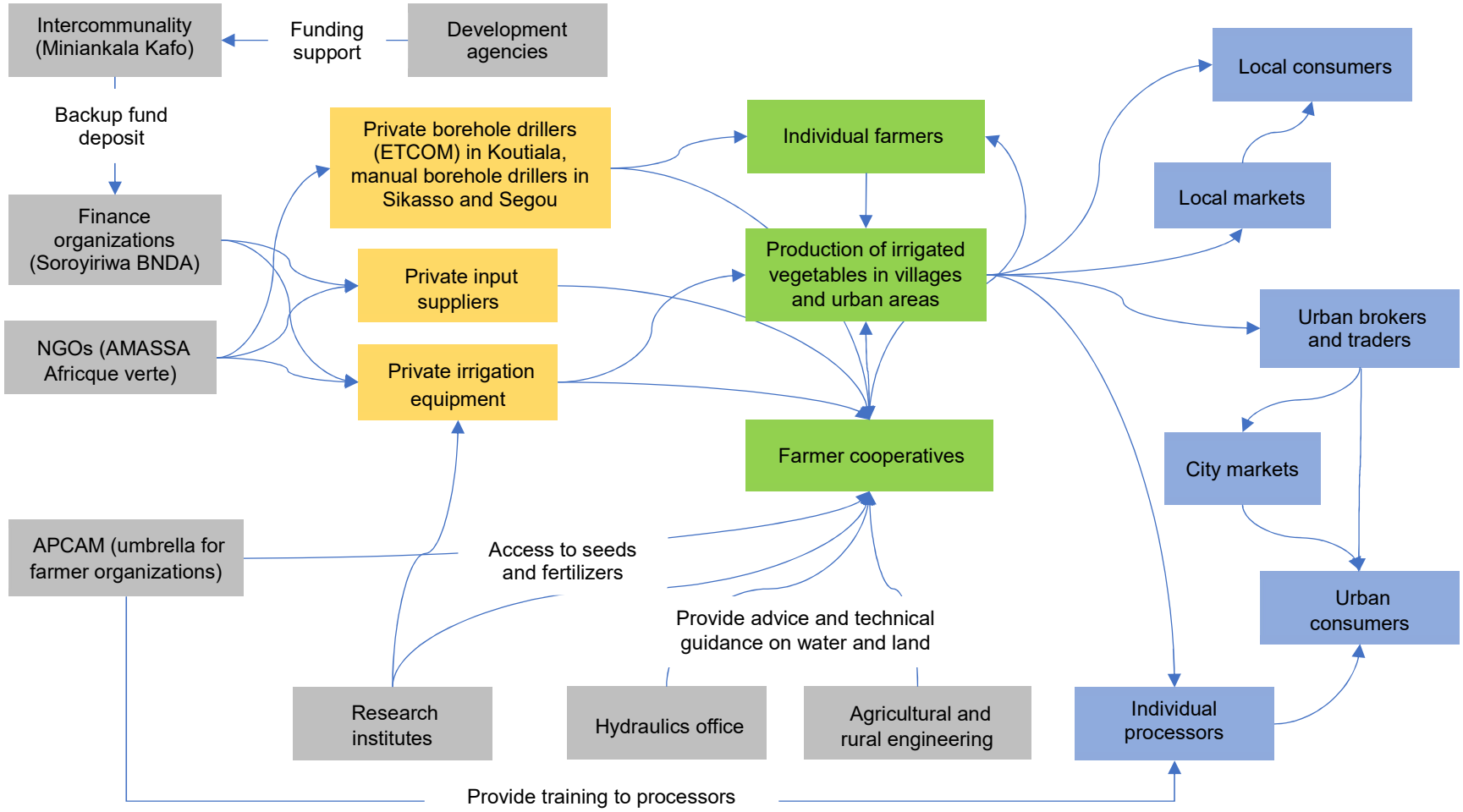
The data analysis used the content analysis to make replicable and valid inferences from data to context, to provide knowledge, new insights, a representation of facts and a practical action guide. As elements of the analytical framework (Figure 1), the lens of these two analyses were used to describe and analyze the practices and experiences of the IVVC in Koutiala to derive general insights into the chain's actors' activities, the way the actors relate to one another through their activities, and the scaling pathways.

When allowed, each focus group interview with farmer irrigators and an individual interview with stakeholders was recorded and then transcribed into English. The recordings were listened to several times to identify and categorize emerging concepts based on similarities and differences between them. This procedure is open-ended, moving back and forth between guiding questions, data and emerging concepts to refine the themes. These emerging issues were analyzed using stakeholder willingness as a yardstick to find context-specific, scalable pathways based on bundles and value chains. Options that stakeholders are likely to engage with are considered acceptable pathways to explore. This analysis led to the scalable hybrid bundle of technologies, practices and services that is likely to strike a balance between affordable options for farmers in local conditions and the minimum support partners are willing to provide.

4. Irrigated vegetable value chain in Koutiala

Figure 2 is an overview of the similarities in the IVVC in Koutiala across the six villages in this study.

FIGURE 2. The irrigated vegetable value chain in Koutiala.



Source: *Authors' elaboration.*

Production and marketing of irrigated vegetable products

In Koutiala, agricultural production consists largely of rainfed cereal crops, such as millet, sorghum, maize and rice, and other crops, including groundnut and beans. These crops are mainly produced during the rainy season, from June to October, and rotate with cotton, which dominates the cropping patterns in the areas around Koutiala. Among cereal crops, rice is the only one that is irrigated. It is grown in lowlands using planning combined with constructing dikes or other private irrigated equipment.

Picture 1a. Water tank and in the technology park in NGolonianasso.

Picture 1b. Solar panels in the technology park in N'Golonianasso.

Picture 2a. Private sprinkler irrigation system on the road to N'Golonianassso.

Picture 2b. Water storage for private sprinkler irrigation system on the road to N'Golonianasso.

Irrigated vegetables and irrigation practices

Vegetable farmers include women and men of different social categories. Irrigated vegetable production starts in the dry season, which extends from November to May. Irrigation is mainly used for vegetables such as tomato, onion, potato, chili pepper, cabbage, African eggplant and dry season okra. These are mostly grown in the dry season under different irrigated systems using (shallow) groundwater.

Although some vegetables, such as okra and pumpkin, are grown in the rainy season, vegetable production is mainly an off-season activity that starts after the rainy season crops are harvested. Traditional hand systems dominate irrigation practices for growing vegetables, especially buckets and water cans. These consist of drawing water from traditional or improved wells and using watering cans and gourds to water the crops twice daily (morning and afternoon). As one farmer said, "Any support to reduce our physical task, which consists of watering vegetable plots twice daily, is appreciated."

These practices are known to negatively affect crop and water productivity, as having an insufficient flow of water from a storage and conveyance system limits the use of other techniques. Depending on the well's depth, pulleys are used to draw the water. Farmers also use motor pumps—at least those who can afford them. "I purchased the pump with the support of another family junior brother working in Bamako," said one farmer. Another farmer said, "I am the only one working the in my garden. Children go to school and cannot help too much, so I purchased the pump using the income from my production."

Along with this basic irrigation system, improved isolated irrigation systems powered by solar modules and pumps are scattered throughout the district of Koutiala (Pictures 1a and 1b). Most are private

investments that resource-rich farmers own and use to produce high-valued vegetables, such as onion, tomato, African eggplant, okra, green bean, chili pepper, leaf vegetables and cabbage. These are mostly funded by research projects and donors for women farmer irrigators. Advanced types of irrigation, such as sprinklers and hose pipes, which resource-rich farmers use, are visible in Pictures 2a and b.

The physical infrastructure of irrigation schemes in the different locations is a mixture of several systems. Along with the dominant traditional wells, watering cans and gourds, there are traces of unsuccessful attempts at introducing mechanical pumping systems with pedals called "Nafassoro." These are visible in, for example, a women's collective garden in Nampossela (Picture 3) and the technological park in N'Golonianasso that Africa Rising funds. The system is no longer in use because it is reportedly too demanding to operate. "These pumps are abandoned, as operating them is painful and demanding in physical effort, especially for women," said one farmer. "Even children who enjoyed operating it at the beginning ended up by not coming any longer."

Picture 3. Abandoned Nafasoro pump in Nampossela.

Borehole irrigation endowed with solar pumping systems is gaining ground in the area. There are four different types. The first is those funded by development agencies and NGOs for the entire village, like the one in Nampossela. The second is those funded by Africa Rising. One is the technological park in N'Golonianasso, which a group of farmers from the village beneficiary use. It is used for field demonstrations to show the potential of new seeds and varieties of vegetables and to control erosion control measures. The third is privately owned solar irrigation systems, including sprinklers scattered throughout Koutiala. The fourth is the government-funded potable water system that, for example, a cooperative of women in Sirakele uses for irrigation.

However, because of scarce water and its inefficient use, flowed storage and conveyance systems cut across all the systems. At the entrance of Nampossela, for instance, a 5-hectare garden well protected with wire mesh fencing has solar modules and a water tank thanks to funding from Malifarm. Yet, the women only use a small portion of the land (less than 0.25 ha) because there is insufficient water. While this forced women to alternate the watering of their vegetable plots, the tank was overflowing, and water was dumped because the automatic closing up system was missing. According to farmers, the limited capacity of the water tank in the N'Goloniasso technological park also restricts the group's potential for vegetable production. In Sirakela, although the community cannot afford to connect to the system, the lack of water limits vegetable production. "When water demand is high, or when the sunlight is weak, the priority is given to household needs," said one farmer. "In the same line within the garden, we arrange alternation among the members for watering their plots as we have only one faucet in the garden. All these practices affect the yields of vegetable crops."

Other pumping systems, for example, are on hold because of maintenance issues in such places as M'Pessoba. Other challenges include managing and governing the solar irrigation system, and there are even reports of cases of people stealing solar modules. "The solar pump in the village has been stolen," said one farmer. "We could not afford to replace it."

Irrigation-related organization is relatively limited in the area. No formal irrigation-related organization exists in the study areas. Contingent rules emerge from practices when farmer groups that share the same resources, such as water sources, face water scarcity. Depending on its availability, producers

ration the water. “When wells dry out or the solar pumping system is flowed, and there is insufficient water for everybody, an alternation is organized to facilitate everyone's access to water,” said the women in Ngolonianasso and Nampossela. “One group of women irrigate their crops in the morning and others in the afternoon.”

In the village of Sirakele, which has a solar pumping system for potable water, a water committee is responsible for managing and maintaining the system. Water is sold to consumers who can afford to pay the fees to connect to the system. The women’s cooperative bought a faucet for their common vegetable garden, and the invoice was shared among all the members involved in production.

Markets and marketing

Vegetable production is for home consumption and sale at local and urban markets. Farmers sell most of their vegetables at local markets to local consumers or brokers and traders coming from other urban areas. At weekly markets, urban retailers buy the bulk of the vegetables produced and transport them all to markets in Koutiala and M’Pessoba. The market for local consumption is common in all areas, and so are the urban markets in the vicinity of the production sites. The locations create conditions for other markets as well. In the urban area of Koutiala, for instance, vegetables are sold at roadside markets, while part of the tomato harvest is exported to neighboring Burkina Faso.

Different **marketing channels** are used to link the supply and demand of irrigated vegetable products. Direct selling requires carrying harvested products to local markets or the nearby urban market. However, some vegetables are sold directly to local consumers and brokers in the farmer’s field. This is the case mainly for farmers organized in groups and working from adjacent fields or within the same vegetable garden equipped by donors. In N’Golonianasso, brokers come from different urban areas and local traders from Koutiala. These brokers have their own network established for collecting products. Along with organized producers, individual producers sell some of their vegetables at weekly markets to local consumers or outside brokers or traders. They use motorbikes, tricycles or donkey carts to carry the vegetables, depending on the distances and the volumes of products, and sell them to brokers from the urban markets. Sometimes, women even carry them on their heads. Social networks are one of the most dominant marketing channels in different markets. “Some of the brokers are from our village but settled in Koutiala or elsewhere,” said one producer. “They are the ones who use to purchase our production. Other brokers are longstanding relations tracing back to the parents of the current broker.”

One new trend in market and vegetable value chain marketing is producers and retailers using mobile phones to exchange information. Organized farmers, mostly women and large growers, use their phones to tell retailers how much produce they must sell and agree on prices. This, in turn, allows retailers to arrange a trip to collect the vegetables from the villages. In this way, they can mitigate some of the challenges related to transportation and perishability. “When you transport vegetables, such as tomato, for example, in the market, whether on the head or by motorbikes, it is difficult to return home with the same load. If for some reason one doesn’t agree with retailers on the price, which is the case in the bumper periods, some prefer to dump their production rather than sell it at a giveaway price.”

Irrigation equipment supply

In Koutiala, ***irrigation equipment suppliers*** are private businesses. Most medium-sized businesses usually engage with large importers and wholesalers from Bamako. Individual business people supply irrigators with an assortment of brands of fuel pumps, solar-powered pumps, panels, plastic pipes, and accessories. They collaborate with the top companies that supply solar equipment in Bamako, such as Horonya, Sonikara and Moustafa Cissé, all of which only sell their own brands of solar equipment. Horonya owns an assembly factory of solar panels in the vicinity of Bamako, while Moustapha Cissé

imports its solar panels and other equipment, labeled MC solar. Along with these companies, specialized private companies, such as EMICOM, Ecotech and Sonikara, provide specific solar-based irrigation products and services.

In Mali, there are many brands of **motor pumps**. These tend to bear the names of the country from which the pump is imported, so traders distinguish them as "China," "Dubai", and "Japan." The price varies from USD 100–200 for the Chinese pump to USD 300–400 for the Japanese, with the pumps from Dubai somewhere in the middle. They are distributed by numerous traders importing pumps from China and Dubai. The price of irrigation pipes is excluded, as irrigators need to buy these separately. Whether from China, Dubai or Japan, using any of these motor pumps for irrigation is challenging. "The high cost of fuel consumption (USD 2 per day), the limited lifetime of motor pumps, and the access to spare parts are among the major challenge," said the irrigators. "In addition, the repair and maintenance are done by local technicians specialized in motorbike, if not, one needs to transport the pumps in the nearby urban area."

At markets, the leading brands of **solar-powered irrigation pumps**, in terms of quality, are Grundfos and Lorenz. These are the most expensive, ranging from USD 2,000 to 3,000, depending on the pumping capacity. A wide variety of cheaper pumps from China are also found on the market, among which the most common is Doyin, though other brands such as INC-CO are also available. The price for these varies from USD 300 to 400. The most affordable and smallest pumps are USD 70 to 100. Combined with the limited number of technicians who can fix these pumps if they break down, the shorter lifespan of the cheapest pumps is the biggest challenge for irrigators who use them. As one farmer said in the interview: "We are aware of the low quality of the cheap pumps, but we have no choice as one needs to start with what you can afford to buy until you afford to buy good quality." Traders also supply **solar panel** pumps. These include cheap (USD 70 to 80 for 200 Wat) second-hand solar panels imported from Morocco and Germany, though there are more expensive new ones, most of which come from China. Horonya manufactures its own brand of new solar panels. The price of the new one is about USD 900 for 200 Wat.

Input supply

Famers access inputs such as seeds, pesticides and fertilizers through two main channels. The first is **private input shops,** called "Arc-en-ciel." Those in Koutiala sell an assortment of vegetable seeds, pesticides and fertilizers to both individual and/or farmer cooperatives. Local businesses own small shops, whereas bigger shops are the branches of larger companies from Bamako. The shops all agree to supply farmer cooperatives with credit—on one condition. "We require a guarantee from financial organizations to provide credit to farmers cooperatives because we experienced a backlog of our credit several times," said one shop owner. "In addition, we also need to be able to pay what we owe to our partners who provide inputs to us from Bamako."

The second channel is **extension services or organizations** such as NGOs and research institutions that provide farmers with access to fertilizer. For example, farmers in the Africa Rising technological park in Koutiala reported that researchers from different institutions did their seed trials in the park, providing inputs, seeds and fertilizer to the trial farmers. Among these organizations are Africa Rising, the Malian Association for Awakening to Sustainable Development (AMEDD) and WorldVeg, which give farmers access to important amounts of inputs at discounted or subsidized prices. "When we get inputs from research institutions, for instance, researchers collect their data, and the production belongs to the producers who can sell it," said one farmer. "As a tradeoff, there is no paid job for the producer during the production period."

Service provision

Extension services provide farmers with counseling, technical guidance, and training on best practices for vegetable production. They are also responsible for controlling the quality of inputs to secure access for farmers to quality inputs. In Koutiala, extension services under the auspices of the regional directorate of agriculture support lowland planning for rice production. They contribute to the measurement and fragmentation of planned lands among beneficiary farmers to secure equity in distribution and to respect gender balance by attributing 10% of land to women and youth.

Financial services are important for farmers in Koutiala to invest in irrigation. Various financial institutions provide formal credit products to farmers, including the National Bank for Agriculture Development (BNDA), the microfinance organization Soroyiriwaso and the Intermunicipality Minaikala Kafo. Established in 2011, with the initial support of the Swiss Development Cooperation, Mininkala Kafo is an umbrella organization representing the 29 municipalities in Koutiala, which allocates 3% of local taxes per municipality to help fund the organization's activities. Miniankala Kafo provides various services, including support for vegetable production, lowland planning, construction of rural roads and finances. One of its programs, the Programme de Développement Economique Local et de Sécurité Alimentaire de Koutiala (PDSU), was funded by a Swiss Development Cooperation for FCFA[2] 2 billion (USD 3.095 million) in 2018. The fund was used to secure a backup deposit of FCFA 50 million (USD 77,400 at Soroyiriwa and FCFA 150 million (USD 232,200) at BNDA. The backup funds aimed to promote farmer access to credit for developing SMEs and income-generating activities, focusing on youth and women. In negotiations with Soroyiriwa, Miniankala Kafo was given a preferential 15% interest rate for the credits with a ceiling of FCFA 2 million (USD 3,095) per farmer. However, no services or products were reported specifically for irrigation. The services and products that financial organizations provide are available for all activities.

Isolated initiatives to support **market access** have reportedly been traced to Koutiala. As mentioned by a representative of an NGO: "Mininakala Kafo, with the support of partners, has in the pipeline the construction of a factory for processing tomato into concentrate. It aims to secure an additional market outlet for the local production of tomatoes. The funding has been granted, but the construction work of the factory by a Chinese company has been delayed due to COVID-19." Other support for market access is provided by other NGOs, such as the Association Malienne pour la Sécurité et la Souveraineté Alimentaire (AMASSA) and Afrique Verte, by training women processors. AMASSA occasionally organizes trade fairs to bring producers together who can show their products to potential clients and consumers. The trade fairs offer spaces for farmers to showcase what they can offer and to connect with potential buyers.

5. Best-fit bundles and farmer segments

The best-fit bundles of irrigation technologies, services and practices

The irrigated value chain in Koutiala has strong support for groups of women farmers in the villages, whether from research projects or donors. Although this is meant to boost vegetable production and reduce poverty among women, it tends to prevent farmers from taking private risks and investment initiatives. Several examples substantiate this project bias: requests for improving the capacity of the water tank in N'Golonianasso, the stolen solar modules in M'Pessoba and the abandoned project-funded Nafasoro pumps in Nampossela, as well as the lack of internal solutions for water shortage in all

[2] Franc Communauté Financière Africaine

of the villages. However, the lack of known alternative options and the asymmetry of information within the landscape could explain the limited local solutions. Therefore, finding ways to expose irrigators in Koutiala to affordable solutions other than project funding is key for scaling bundles of irrigation technologies, practices and services while gradually deconstructing the mindset of depending on funding from projects and other external sources.

This mindset, which dominates the area, should be creatively replaced with conditions that foster private, individual or group investments in these irrigation bundles, while considering the challenges of using existing technologies. In this context, hybrid irrigation technologies, practices and services could be a scalable bundle in Koutiala.

Water lifting technologies. Most resource-limited and resource-poor farmers cannot afford motor pumps, and only a limited number of resource-rich farmers can, making them difficult to scale. In addition, the daily costs of fuel and maintenance issues suggest that these pumps will likely have limited outreach if proposed for scaling. For this reason, introducing and using solar-powered irrigation technologies that every segment of farmers can use could be a promising alternative. However, this requires finding solutions to water challenges that farmers face during periods with less sunlight. Knowing this, the following irrigation bundles could be proposed for scaling.

The solar-powered SF2 alike pumps could be bundled with affordable motors pumps that can be used when there is less sunlight. This bundle can harness the potential of each technology while offsetting its pitfalls. As such, having the option to use a solar pump when there is a drop in sunlight would likely reduce the fuel and maintenance costs of motor pumps.

However, scaling this bundle might require credit services and practices that, rather than deterring farmers, will likely encourage them to invest resources into such technologies. To put this in place, financial organizations, support NGOs, government organizations, equipment suppliers, and farmers could come together to establish win-win credit services and practices while learning from previous experiences of credit backlogs or failures.

Water storage. In Koutiala, water is mainly stored in locally constructed iron water tanks that are supported by an iron frame. The cost of such water storage, including transportation and installation, varies from USD 600 to 1000 according to the distance between the steel workshop and the irrigation site. The plastic tanks are mostly for domestic use. They are less visible in rural areas and vegetable plots for irrigation. Yet, these iron water tanks are too expensive for most resource-limited and resource-poor farmers to buy. As an alternative, second-hand 200-liter barrels recovered from oil factories could be manufactured and scaled to provide these farmers with affordable water storage.

Water application and irrigation practices. There are two types of irrigation practices. Currently, farmers use watering cans to fetch water directly from the tank's outlet to irrigate their vegetable plots, so they walk between the plots and the outlet. Alternatively, farmers could use flexible pipes to bring the water to the plots. Given the conditions of Koutiala, it is possible to scale this practice by using recovered second-hand barrels for water storage. Using flexible pipes would reduce the effort required for farmers to go back and forth between the water outlets and their vegetable plots.

Extension, market links and financial services. The role of extension entails counseling, technical guidance and training on the best practices for vegetable production. They also help distribute planned lands among beneficiary farmers to secure equity. Along with the bundle of irrigation technologies suggested in this study, several scalable practices and services are possible.

Along with counseling and technical guidance, brokering access for farmers to affordable irrigation technologies, practices and services could be an added extension practice to scale. This brokerage can

take various forms. It could consist of extension offices and other government organizations together playing the role of guarantor for farmers to access credit from financial organizations to buy irrigation bundles. The willingness of farmers to invest their own resources to buy affordable second-hand barrels to store water on their owned land could be the key criteria of eligibility for such credit. The success of that practice could be conditional upon the willingness of financial organizations to open a credit line for farmers to buy irrigation technologies, as no services or products were reported specifically for irrigation. Stakeholders could discuss the appropriate mechanisms to guarantee their interests while making sure that any credits are repaid. These mechanisms should be autonomous to prevent project bias. To ensure financial organizations are repaid, stakeholders could help credit beneficiaries market their vegetables grown using the irrigation technologies bought on credit.

Taking all this into consideration, the best-fit scalable bundle would be a combination of (1) solar and motor pumps, (2) second-hand barrels for water storage, (3) flexible pipes for irrigation and (4) support organizations that can get farmers to access to credit to buy irrigation technologies and then help them sell the vegetables they grow from these purchases.

Farmer segments for the best-fit bundles

Table 2 lists the farmer segments and potential clients for bundling technologies. In Koutiala, **resource-rich farmers** are those who own large portions of land. Production-wise, resource-rich farmers tend to be less involved with vegetables and more with trees. Their financial capacity allows them to invest important funds to buy irrigation technologies and equipment, including solar panels and pumps. They can also afford to hire labor to work on their farm. They have easy access to extension services and input provisions they can afford to buy. These farmers are rich private businessmen who own oil extraction factories and other businesses but practice farming only as a hobby.

TABLE 2. Market segments and potential clients for the bundle of technologies.

Characteristics	Resource-rich farmers	Resource-limited farmers	Resource-poor farmers	Farmer cooperatives and groups
Access to land and water resources	- Own large portions of land - High capacity to control water sources	- Own irrigated land - Partial control over water resources	- Own inherited portions of cultivated land - Access is limited mainly to groundwater using cans and buckets	- Own collective vegetable gardens equipped by support organizations along with individual cultivated land - Access to groundwater
Current irrigation practices and investment	- Improved irrigation system managed by individual farmers - Irrigated crops (tomato, onion, potato, chili pepper, cabbage, African eggplant and okra)	- Individual irrigation management - Combination of flexible pipes and watering cans - Irrigated crops	- Individual/group management - Use of watering cans and buckets for irrigation - Irrigated crops	- Individual and/or collective irrigation management - Irrigated crops
Access to different services	- Easy access to extension services, inputs and markets - Self-sufficient, so there is no need to resort to financial services	- Patchy access to extension services and inputs - Access to financial services but reluctant to take out individual credit	- Difficult to access extension services, inputs and marketing services - Do not use financial services	- Easy access to extension - Rely on NGO support - Difficult to access inputs and marketing services

Financial capacity	- High financial potential to invest in irrigation technology bundles as individuals	- Medium financial potential to invest in these bundles as individuals	- Very limited financial capital, especially for female farmers - Low potential to invest in the bundles	- Limited financial capacity to invest in the bundles - Potential to collectively invest in the bundles
Preferences for technology bundles	- High capacity to invest in bundles without credit services	- Low to medium capacity to invest in bundles - Need credit services adopted to their conditions - Need marketing support	- Low capacity to invest in bundles - Require credit services and inputs to fit their needs - Need marketing support	- Low to medium capacity to invest in bundles as a group - Need support for collective financial management and mobilization

Source: Authors' elaboration.

Resource-limited farmers own land but have limited financial capacity to invest in irrigation technologies and equipment. They can afford some equipment, such as fuel-powered pumps or solar panels and pumps, but not fully-fledged equipment to meet their irrigation needs.

While NGOs and development partners often support women's groups, resource-limited and resource-rich farmers tend to rely on their own ability to invest in irrigation technologies, with or without credit from financial organizations. "Clients who mostly purchase our equipment are individual farmers who can afford it," said an equipment trader in Koutiala. "We don't give equipment at credit as we don't get it at credit in Bamako. What we do, however, is to secure a minimum profit margin for those who can afford it to keep the business flowing."

Resource-poor farmers may or may not own some portions of inherited land, but they have no financial capacity to purchase even some equipment. They rely on manual irrigation using cans and buckets.

Farmer cooperatives and groups are mostly women who are organized and supported by NGOs and research programs. They grow vegetable gardens that are surrounded by wire fences. Although they have access to extension services, they rely on project funding and seldom resort to financial services to improve their irrigation practices.

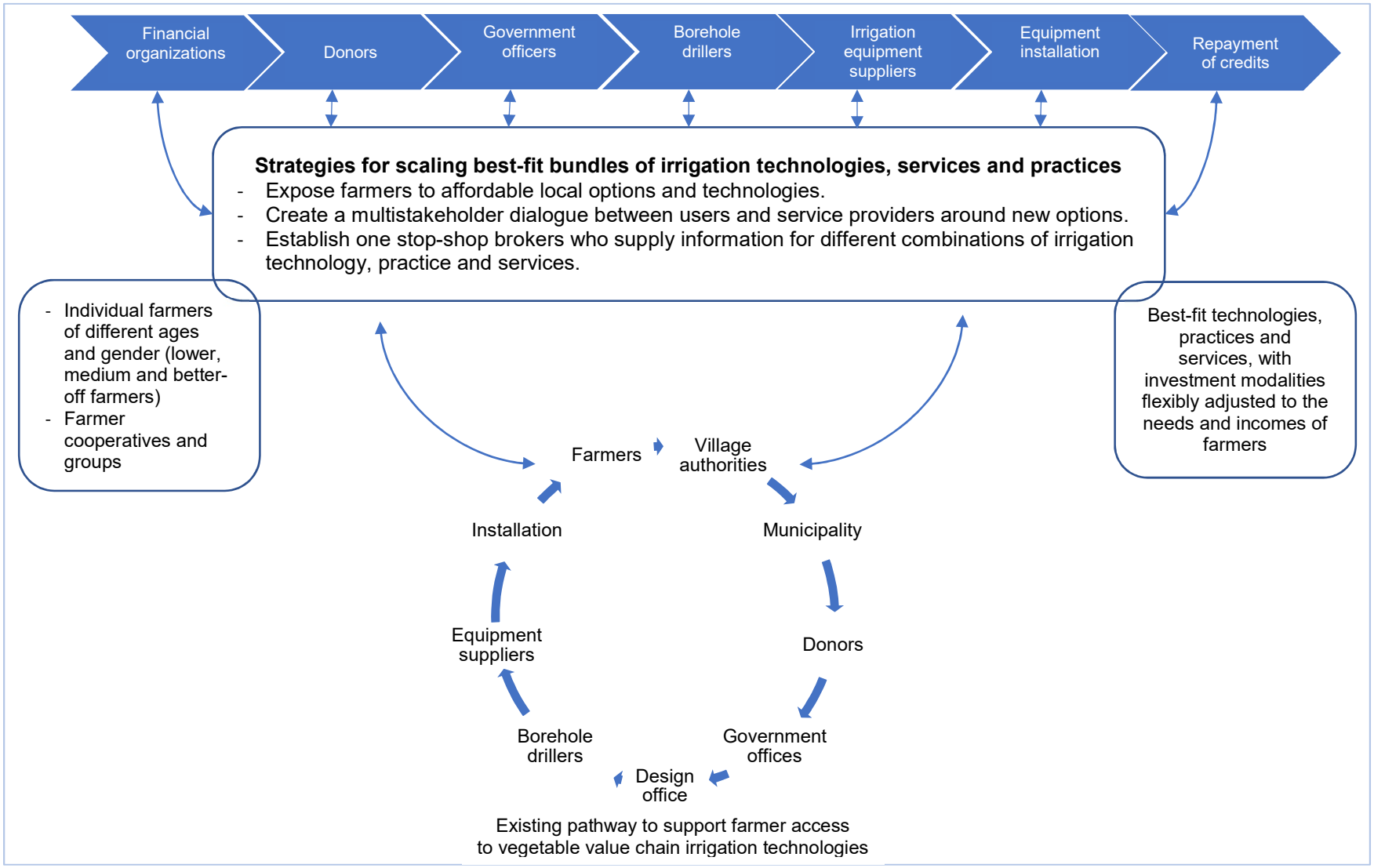
6. Exposure-based pathway to scale the best-fit bundles

The lower part of Figure 3 shows the current pathway used to help farmers in Koutiala access irrigation technologies to grow vegetables. Building on this, the **exposure-based pathway** is proposed to scale the best-fit bundles. As shown in Figure 3, it includes three components:

1. Expose farmers to affordable local options and technologies.
2. Create a multistakeholder dialogue between users and service providers around new options.
3. Establish one-stop brokers who supply information for different irrigation technologies, practices and service combinations.

Presenting farmers with unknown options will require creating enough space to introduce solar-based irrigation technologies, such as for farmers who face water shortages despite existing investments. This component should focus on helping farmers discover other options in real life, boosting their willingness to invest on their own, and gradually moving away from the project bias that dominates the current pathway. The main activity requires organizing a supply and demand event to hold demonstrations at some existing sites so that farmers can see how the technologies could help them.

FIGURE 3. An exposure-based pathway to scale the best-fit bundles of irrigation technologies, practices and services.



Source: Authors' elaboration.

Creating a multistakeholder dialogue between users and service providers around new options includes two parts. One is discussing the conditions under which farmers are willing to engage in the processes inherent to the exposure-based scaling pathway of irrigated technologies, practices and services. The other is what would constitute a win-win scenario for farmers to be exposed to new technologies. Activities in this component include involving microfinance organizations and discussing the role of stakeholders to make sure that private companies supplying the technologies are paid for their equipment.

To sustain the supply-demand link over time, stakeholders could create a one-stop shop in Koutiala that brokers information and partnerships among them. This would involve providers such as private irrigation and input supply companies to promote different products and microfinance organizations to make it easier to access credit services.

The extension workers from research, organizations, and NGOs could collaborate to facilitate and reflect on the best exposure-based scaling pathway. The role of the research organizations would be to create a dialogue among different stakeholders and document the whole process. At the same time, NGOs would connect farmers with local communities and follow the process. The extension offices would collect crop data and help with assessment and scaling.

Factors influencing the exposure-based pathway

This section describes the factors that would either help or hinder an exposure-based scaling pathway, and the key actions and conditions needed for the success of a bricolage pathway to scale irrigation technologies, practices and services.

Hindering factors

In the literature, there is consensus that a major problem is a potential addition to the already ***high initial costs*** of irrigation equipment, which is a huge challenge for scaling such technologies (Diarra and Akuffo, 2002; Kamwamba-Mtethiwa et al. 2016; Abdoulah Mamary 2018; Kergna and Dembele 2018). This high cost is visible at different levels and tends to deter resource-poor farmers from exploring innovative practices. This explains why most resource-poor farmers, whether individuals or groups, tend to wait for additional solutions from projects and donors because they cannot afford them. As many farmers said in the interviews: “It is too expense—that is why we even don’t explore,” said one farmer. “There is no point to explore things you cannot afford.” Two factors make this problem worse. One is the lack of information on the availability of cheaper alternative options, which reinforces the overreliance of poor farmers on donors through projects and programs. The other is the lack of options these farmers can afford.

In Koutiala, there is only one hydraulic worker for the entire district. This, combined with the security situation in the country, means that not everyone gets the same information and that communities find it difficult to access appropriate sources of information. Even when they get help from the hydraulic office, most farmers ignore their advice because they do not know the normal procedure. Whether consciously or unconsciously, they take the shortcut of hiring a borehole driller. As the hydraulic office explains, most irrigation projects fail because this shortcut is a result of poor design. This is also confirmed by some private investors who did not consult with a specialist before hiring borehole drillers. “I am the one who knows what I want to do on my land,” said one private investor. “I then decide what service and equipment fit best to my needs. I look for it on the market; I purchase it when I can afford it.”

On the other side, borehole drillers describe the geological situation in Koutiala as challenging. "The 5 m^3 per hour standard debit required in the specifications of the borehole seems not reachable in Koutiala," said one driller. "Sticking to that standard, the common 3 m^3 per hour commonly reached in practice is considered by donors as an unsuccessful borehole. These discrepancies may lead to donors denying the payment of the services provided by drillers."

The ***high requirements of donors*** in terms of who can afford the guarantee to be eligible for support or not also makes it difficult to arrange funding for new irrigation technologies. This might also limit the outreach of funding projects and programs that could help scale these technologies. The eligibility requirements from donors, combined with the large amount of paperwork, could also deter farmers and other stakeholders from making a move or following the normal procedure for acquiring irrigation facilities. If they do and successfully acquire funding, the next challenge would be overcoming delays in implementation. The village of Zanzoni is currently in this situation. According to one villager, "The village has been longing for a borehole project granted by the government but taking time to be implemented." This partly explains why better-off farmers, who can afford it, bypass the normal procedure to follow their own way.

The ***uncertain implementation of support*** makes it difficult for farmers and farmer cooperatives to benefit from interventions. Support organizations are the ones that guide the funding from NGOs and development agencies through the process. Some of these organizations follow normal procedures, but others do not. In any case, sustainability is another, even bigger, challenge once a project is implemented for a village or farmer cooperative. Spare parts might be inaccessible in the area or too expensive for the local communities to afford without external support. As for maintenance fees are either not set aside beforehand, or it is too late when the beneficiaries realize they need them. The main reason is that communities are dominated by the vicious circle of the project mindset in which external support projects, donors or the state are expected to provide and sustain everything that is collectively needed. This strong reliance on projects is audible in any conversation in the area. As one farmer said, "Unless we are helped, we have no other solutions as we cannot afford this and that." This explains why several projects are abandoned because of maintenance issues, despite the important initial investments.

Strong project reliance is also visible in the limited willingness to pay for services. We visited a field with contour bonding in Sirakele. Zamoho provided the contour bonding, funded by Africa Rising under the auspices of its partner NGO AMEDD. The site aimed to showcase contour bonding, and candidate farmers were supposed to pay FCFA 5000 per request for Zamoho's service. Apart from the demonstration site, we came across no other contour bonding during the fieldwork. The cases of equipment out of order or abandoned substantiate the lack of willingness of farmers to pay for services themselves. Stone lines are another well-known practice that is seldom visible in the area. For example, farmers in Koutiala said visitors rarely use stone lines, even though communities are aware of their relevance, the distance and effort required to access stones and the investment needed for a donkey cart. Less expensive practices, such as using straw to obstruct runoff water, are the most visible and confirm the challenge of encouraging farmers to pay for services.

Such a fragmented playing field creates ***space for competing claims, conflicts of interest and the blame game*** among different stakeholders, especially between private businesses and government offices. The government offices follow official scripts, stating, "water resources belong to the state, and any water initiative should be known and recorded in their database called sigma." Meanwhile, private businesses blame the government offices for unfair

competition: “The government offices play the role entitled to private businesses using the means provided by the state. This is combined with the limited number of staff, for instance in the hydraulic office very often vacant with no one to respond to the inquiries from communities or individuals in need.”

Finally, finding the ***right organization*** to broker and sustain information and partnerships over time could be the main hindering factors. This could require an initial investment in a structure, like a one-stop-shop, to play this role and then high operational costs to maintain it and make it efficient.

Enabling factors

One of the enabling factors for the exposure-based pathway is the ***growing interest*** of farmers, support organizations, policymakers and all stakeholders involved in the IVVC. Another is the ***existing investments*** that could host new technologies to replace or supplement the initial ones. The product market is diverse, and the various irrigation equipment companies, actors and local technicians can adapt to different options. The ***availability of well-protected collective gardens***, whether funded by research projects or donors, creates space for testing new options. The potential of these gardens is not well known because of flowed irrigation systems or abandoned technologies, so best-fit technologies could be adapted to existing investments to improve production.

Key actions and conditions

To scale the best-fit irrigation bundles in a sustainable way, it is essential to gradually break the project mindset's vicious circle by reversing farmers' overreliance on donors and stimulating their willingness to take local initiatives. As such, it is important to find the right ways to encourage farmers to invest their own resources in sustainable technologies, practices and services. To be inclusive, the process could explore the potential mechanisms with relevant stakeholders to customize the investment and repayment modalities to the needs and social categories of the farmers. Gleitsmann et al. (2007) stress this need for flexibility in institutions and practices involved in managing water supplies in rural communities to adeptly respond to their diverse needs and preferences. The missing link in all this could be finding a broker organization with the potential to connect stakeholders to give farmers access to the right information and the best-fit technology, practice or service. Finding one could trigger flexible mechanisms and make farmers more willing to invest in irrigation technologies. Such a broker could act as a one-stop-shop that guides farmers in the right direction at every stage—from the start of the initiative to the delivery of the project, and then eventually the payment of contributions or repayment of credits. This could prevent farmers from being deterred while helping them navigate the daunting process of finding information, supporting funding, implementing the project, and identifying a broker organization or creating a startup to play that role is essential. One of the key conditions is creating and keeping an up-to-date repertoire of actors and stakeholders involved in vegetable value chain-based irrigation in Koutiala. Another accompanying action could be creating a vegetable business network to give farmers better access to markets for the vegetables they grow.

7. Conclusion

Irrigated vegetable production is an off-season activity in the context of the monomodal cropping system of Koutiala. The great potential of the IVVC is still untapped because of the challenges related to the difficulty in accessing irrigation technologies, practices and services. To do so, this study proposes a hybrid scaling pathway to access all three. It

combines cheap second-hand materials that are available and affordable for farmers with expensive equipment that external support can provide. This can reduce the initial investment costs for both farmers and support organizations and encourage farmers to take more initiative and be willing to invest in irrigation technologies.

The main challenge to this is the high cost. The cost tends to limit the outreach of irrigation technologies to resource-rich farmers while suppressing the willingness of resource-limited and resource-poor farmers to invest their own resources into such technologies.

The scaling pathway could increase their outreach by tailoring best-fit irrigation bundles to farmers. Although the availability of different factories, technicians and service providers makes the scaling pathway possible in Koutiala, the current project mindset among farmers could prevent it from even getting off the ground.

However, the most important factor is finding consensus among stakeholders. To do so will require bringing them all together to engage in and discuss the exposure-based scaling pathway while openly securing the interests of each category of stakeholders. Above all, this will determine the success and sustainability of the proposed pathway.

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