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Getaw Tadesse, Mahamadou Tankari, Ismael Fofana, Racine Ly, Sangare Saadatou, and Bachir Ousseini

Feasibility, Scalability and Ex-ante Impacts of Small-scale Irrigation Technologies in Niger

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Getaw Tadesse, Mahamadou Tankari, Ismael Fofana, Racine Ly,
Sangare Saadatou, and Bachir Ousseini

AKADEMIYA2063 - Kicukiro/Niboye KK 341 St 22 I P.O. Box 1855 Kigali-Rwanda
Email: kigali-contact@akademiya2063.org

*AKADEMIYA2063 | Lot N*3 Almadies | BP 24 933 Ouakam Dakar-Senegal*
Email: dakar-contact@akademiya2063.org

www.akademiya2063.org

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Authors

Getaw Tadesse is the Director of Operational Support at AKADEMIYA2063: gtadesse@akademiya2063.org
Mahamadou Tankari is the Interim Director, Department of Capacity and Deployment, at AKADEMIYA2063: mtankari@akademiya2063.org
Ismael Fofana is the former Director of Capacity and Deployment at AKADEMIYA2063: i.fofana@outlook.com
Racine Ly is the Director of Data Management, Digital Products, and Technology at AKADEMIYA2063: rly@akademiya2063.org
Saadatou Sangaré is the Head of the Department of Studies and Research, Public Policy Analysis and Government Action Evaluation Unit at the Université de Tahoua, Niger: saadalk@gmail.com
Bachir Ousseini is a national irrigation expert for the Pro-Sahel project at the Permanent Secretariat of the Small-Scale Irrigation Strategy in Niger: bachousseini@yahoo.fr

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Contents

ACRONYMS

ANPIP	*Association Nigérienne de Promotion de l'Irrigation Privée* / Association for the Promotion of Private Irrigation in Niger
FAO	Food and Agriculture Organization
CFA	*Communauté Financière Africaine* / African Financial Community
CGE	Computable General Equilibrium
DREAM	Dynamic Research Evaluation for Management
DWFI	Daugherty Water for Food Institute
GDP	Gross Domestic Product
MP	Motor pump
Ha	Hectares
IRR	Internal Rate of Return
IFPRI	International Food Policy Research Institute
NGO	Non-Governmental Organization
O&M	Operations and Maintenance/Management
PIP2	Private Irrigation Promotion Project
PRS	Poverty Reduction Strategy
RDA	The 2003 Agricultural Policy
RSDS	Rural Sector Development Strategy
SAM	Social Accounting Matrix
SNDI/CER	*Stratégie Nationale de Développement de l'Irrigation et de la Collecte des Eaux de Ruissellement* / National Strategy for the Development of Irrigation and Runoff Water Collection
SPIN	*Stratégie de la Petite Irrigation au Niger* / Strategy for the promotion of Small-scale irrigation in Niger
SSA	Africa south of the Sahara
SSI	Small-scale Irrigation
SWAT	Soil and Water Assessment Tool

Abstract

This study explores emerging small-scale irrigation (SSI) technologies and their possible impacts on growth and poverty reduction in Niger. A modeling approach integrating biophysical and economic models was used to estimate the feasibility and adaptability of four selected technologies: treadle pumps, motor pumps, small reservoirs, and communal river diversions (or water diversions). A Computable General Equilibrium model (CGE) adapted to the country context was developed to simulate the impacts of these technologies on economic growth and poverty reduction. In addition, the study used geospatial analysis to identify the best locations for SSI expansion. In Niger, the treadle pump, motor pump, small reservoirs and communal river diversions can be expanded over 133,000 hectares (ha), 136,000 ha, 98,000 ha, and 6,000 ha, respectively. These technologies have the potential of reaching up to 4.6 million people in rural areas. Irrigation expansion could boost the national economy by about 5.5 trillion FCFA and generate an agricultural value-add of about 4.0 trillion FCFA. It would also reduce the number of the poor by about 648,612 people (82-86 percent of whom live in rural areas), indicating a significant spin-off effect following investments in small-scale irrigation. The most feasible areas for this expansion of irrigation are located in western Niger. The study proposes a roadmap for SSI development in line with these results and with existing frameworks at continental and regional levels.

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1. INTRODUCTION

The need to create resilient food systems through the development of key value chains for climate resilient agricultural products, while strengthening the links between science, policy and strengthening of food and nutrition security for vulnerable communities, has never been more urgent. Global attention is once again focused on food security following the UN Summit on Food Systems in September 2021, which laid the groundwork for transforming global food systems to achieve the Sustainable Development Goals (SDGs) by 2030 in particular Goals two and one. The rising number of young people coupled with the growing demand for food and jobs is a continental and global concern.

The importance of irrigation in improving agricultural productivity and food security, promoting climate-resilient agriculture, as well as creating jobs in rural Africa in general and the Sahel in particular, is no longer in doubt. Previous efforts to promote improved seeds and fertilizers have contributed significantly to the growth of agricultural production through increased land productivity (Tefera et al. 2021). However, agricultural labor productivity has remained stagnant (Tefera et al. 2021). As farmers who depend on rain-fed agriculture are only active for three to six months annually, focusing on irrigation is key to improving agricultural labor productivity. Irrigation enables farmers to grow crops throughout the year and depending on the crop, to harvest more than once a year. This induces an increase in labor productivity, which is more crucial than land productivity in raising incomes and reducing poverty.

There is growing political will and commitment to support the development of small-scale irrigation (SSI) in the region as governments develop specific strategies for its promotion and expansion. Niger launched its National Irrigation Development Strategy in 2005 with the aim of improving the contribution of irrigated agriculture to agricultural gross domestic product (GDP) from 14 percent in 2001 to 28 percent in 2015. In 2012, a specific SSI strategy was integrated into Niger's strategy for food and nutrition security and sustainable agricultural development (the 3N Initiative - Nigeriens feed Nigeriens). In addition, regional and international development partners, alongside local and national governments, are increasingly interested in investing in small-scale irrigation. The realization that smallholder farmers can play a key role in the development of irrigation in Africa south of the Sahara, has made water use by these farmers a key political priority (DWFI, 2018). This perspective was a crucial focal point at a 2018 policy forum jointly organized by the World Bank and the Daugherty Water for Food Institute (DWFI, 2018). In September of the same year, the World Bank, in collaboration with the African Development Bank (AfDB) and the Alliance for a Green Revolution in Africa (AGRA), launched the "farmer-led irrigation initiative" (World Bank, 2018). The African Union (AU) also developed its continental framework for small-scale irrigation development in 2020 (AU, 2020).

Niger has 15 million hectares (ha) of agricultural land (11 percent of the country's total area), including a significant potential feasible area (Gouvernement du Niger, 2015) that covers an estimated 11 million ha. However, until 2020, only 1.032 million ha of land had been developed. In 2012, the potential feasible area extended to about 93,150 hectares. Between 2011 and 2020, efforts to control water and build hydro-agricultural facilities led to an expansion of the potential feasible area. The area under SSI increased from 94,733 ha to 207,789 ha, an average annual increase of 9.1 percent made possible by the construction of 179 weirs, construction or rehabilitation of 40 dams and development of 145 basins. In line with this dynamic and untapped potential, a project dubbed Pro-Sahel (Innovation and Technology in Small-Scale Irrigation Systems for Small-Scale Producers in the Sahel) was developed with the aim of identifying scalable technologies, innovations, and investment pathways to extend irrigation to small-scale producers in Niger and Burkina Faso. Focusing on the case of Niger, this report presents evidence that is intended to guide decision-making on SSI development in the country.

The report structure follows. After the introduction, Section 2 describes the state of small-scale irrigation in Niger. Section 3 describes the methodology used for estimating water availability, priority crops, feasibility, and scalability of irrigation technologies. Section 4 presents the results of the analysis on irrigation potential and the impacts of four irrigation technologies tested in Niger, i.e., treadle pumps, motor pumps, small reservoirs and communal river diversions. The final section of the report provides concluding remarks.

2. THE STATE OF SMALL-SCALE IRRIGATION IN NIGER

2.1 Agricultural and Irrigation Development Policy Initiatives

Located in the Sahel region, the country of Niger extends over 1,267,000 square kilometers (km^2), two thirds of which are desert. Niger's total population in 2021 was estimated to be 22 million and the population density in 2020 was ten people per square kilometer. Notably, 90 percent of the country's population is concentrated in a 200 km strip of land in the south, where rainfall favors farming and keeping of livestock (FAO, 2005). Niger's economy is largely based on subsistence agriculture and the predominantly grown crops are millet, sorghum, rice and cowpeas. Cultivation of rain-fed crops is linked to the traditions and dietary habits of rural populations, which are shaped by poor access to water during the dry season.

Niger built its first large hydro-agricultural facilities on the floodplains of the large permanent rivers flowing across the country, such as the Niger River. From independence until the great drought of 1973, the country's agricultural policy sought to intensify cultivation of irrigated and rain-fed crops with an emphasis on export crops (peanuts and cotton), which were the main targets of the fertilizer distribution policy.

The 1973/74 drought marked a turning point and led to reforms in agricultural policy which now prioritized self-sufficiency in food production. The new reforms focused on shrinking food deficits through intensive agricultural and productivity improvement initiatives as well as development of hydro-agricultural facilities. These were implemented through various projects that covered the entire country and involved several public firms as well as a proactive policy of subsidizing agricultural inputs and prices.

Since 1982, Niger's agricultural policy has generally become more aligned with the country's structural adjustment processes to better achieve macro-economic balance and greater efficiency in the work done by public institutions, while promoting private sector development. During the structural adjustment period, the Rural Sector Development Strategy (SDR - *Stratégie de Développement Rural*) focused on four main objectives: i) Improving management of natural resources; ii) Organizing the rural sector and redefining government's role there; iii) Ensuring the population's food security; and iv) Intensifying and diversifying agricultural production. Many projects and programs were implemented during this period, including the World Bank's Private Irrigation Promotion Project (PIP2).

Two more generations of the rural sector development strategies (SDR) followed the first launched in 1982. However, in 1992, there was a paradigm shift as the new SDR focused on food security and abandoned the prevailing concept of food self-sufficiency. This change prompted the country to strengthen irrigation and adopt SSI in response to the population's food needs. This strategy led to the implementation of many development programs, including irrigation and land restoration programs as part of the climate adaptation actions and programs linked to the overall strategy for water resources development. Indeed, the strategy highlights the importance of such programs in laying the foundations for sustainable agricultural development. Following recent monetary, economic and institutional reforms (government disinvestment and liberalization of economic activities), emerging investment opportunities have been taken up at national and regional levels.

The 2003 SDR, adopted by the Government of Niger as part of its agricultural policy, coincided with the implementation of the poverty reduction strategy (SRP - *Stratégie de Réduction de la Pauvreté*). This SRP assigns the rural sector a leading role in driving economic growth and is structured around three key areas: i) Promoting rural people's access to economic opportunities creating the conditions for sustainable economic growth in rural areas; ii) Risk prevention, improved food security and sustainable management of natural resources; iii) Strengthening the capacities of public institutions and rural organizations to improve rural sector management.

The first framework of the National Strategy for the Development of Irrigation and Runoff Water Collection (SNDI/CER - *Stratégie Nationale de Développement de l'Irrigation et de la Collecte des Eaux de Ruissellement*) was launched in 2005. At the time, irrigation development was still closely linked to agricultural policy. The SNDI/CER sought to, improve the contribution of irrigated agriculture to agricultural GDP and increase it from 14 percent in 2001 to 28 percent in 2015 (SNDI/CER, 2005). This would be achieved by: i) Establishing a favorable framework for investment and private irrigation; ii) Ensuring integrated and sustainable management of production capital (water, soil); and iii) Strengthening the capacities of public institutions and private organizations involved in irrigation development and runoff water collection. However, this strategy mainly describes the principal avenues for intervention in large-scale irrigation projects and does not give sufficient consideration to small-scale, community-based irrigation.

The SSI strategy was finally introduced in 2015 to meet the specific needs of the sub-sector. It has been integrated into a strategy for food and nutrition security and sustainable agricultural development (the 3N Initiative), which brings together all interventions in Niger's rural areas since 2012. Irrigation is the first operational program of the 3N Initiative, which supports individual and collective irrigation systems to increase agricultural productivity and strengthen the resilience of rural producers to climatic hazards (Government du Niger, 2017).

The Strategy for the Promotion of Irrigation in Niger (SPIN - *Stratégie de Promotion de l'Irrigation au Niger*) defines small-scale irrigation as, "any autonomous hydro-agricultural operation of controlled size, individual or collective, economically viable and ecologically sustainable, equipped with technologies adapted to local know-how" (Gouvernement du Niger, 2015). One of SPIN's main challenges is to ensure that agricultural producers have access to advisory services. In 2016, the advisor-producer ratio was 1: 1000 which is far from the FAO-recommended ratio of one advisor for 200 to 300 producers.

Between 2011 and 2020, efforts to control water and build hydro-agricultural facilities increased the extent of the potential feasible areas. The area under SSI increased from 94,733 ha to 207,789 ha, an average annual increase of 9.1 percent made possible by the construction of 179 weirs, construction or rehabilitation of 40 dams and the development of 145 basins. In addition, 5,214 ha of hydro-agricultural projects and 2,807 ha of land have been developed/rehabilitated for small-scale irrigation. The level of water controlled increased by 44 percent over the period. Producers received 7,903 tons of crop seeds, 37,694 motor pumps and large quantities of cassava cuttings as part of the 'cassava cuttings operation'. They also received support for the construction of wells for small-scale commercial farming. Overall, irrigated production increased by an average of 24 percent per year over the 2011-2020 period i.e., from 169,166 tons of cereal equivalent in 2011 to 1,032,023 tons in 2020 (Figure 1). This progress has been achieved due to the expansion of irrigated areas, increasing the volume of water controlled and the campaigns on irrigated production carried out among producers.

2.2 Introduction of Small-scale Irrigation Technologies

Farmers in Niger use different irrigation technologies with varying degrees of success. This sub-section presents an overview of the different technologies that have been introduced to Nigerien farmers. It examines their advantages and disadvantages as a step towards the selection of scalable technologies.

Drilling and water collection technologies

Several manual water collection technologies have been tested and popularized in Niger, namely manual drilling, well drilling (borehole), wash bore drilling (water throwing) and hybrid drilling systems. Manual drilling is a lowlt cost technologythat is easy to install, is environmentally friendly and has a long service life. However, it is not suitable for colloidal aquifers and its filter cloth is fragile. Given these considerations, manual drilling can be expanded into alluvial aquifers while avoiding pond and river margins. Further, the emerged portion must be pressurized PVC. Advantages of a borehole are the speed of realization, lack of siltation, high flow rates and the low costs involved (estimated at 25,000-49,000 FCFA). On the other hand, it is not suitable for colloidal and gravelly aquifers and its filtering cloth is fragile. Considerations for its expansion include avoiding the areas around ponds and rivers. Wash bore drilling has the advantage of reduced costs and accelerated development. However, it is not suitable for colloidal and gravelly aquifers and requires a previously constituted water reserve. Finally, the hybrid drilling system reduces operation time and costs. However, it is not suitable for colloidal and gravelly aquifers and requires a previously constituted water reserve.

Mechanical water collection technologies cover boreholes and other wells made using a low-cost machine. Motorized augers which are used for deep drilling (beyond 25m depth), or in rock formations that are too hard to penetrate with manual drilling techniques, are a typical example of this. In this case, manual force is replaced with a heat engine or electric motor. Despite its high costs, the motorized auger is the only available option when drilling in hard geological formations. This technology is suitable for use where bedrock is an obstacle to manual drilling techniques. With its speed of execution and the quality of the drilling, it is a suitable replacement for manual pile drilling. However, the cost of motorized drilling is generally five to ten times higher than that of manual drilling.

Treadle pumps

These are used to pump water for crops and are operated either by foot or by hand. The Bangladesh pump and the Gagéra suction pedal pump are better suited for smallholders who pump water for use in small areas (less than 0.5 ha). The estimated cost of these pumps in Niger is less than 60,000 FCFA. The manual pump (estimated to cost 80,000 FCFA) is especially appreciated by women, even though it can be exhausting to use. The Bangladesh pedal pump (large diameter) is produced by a Senegalese company. It can draw water from a maximum depth of 2.50 m and enables gravity-fed irrigation by filling canals, ponds and reservoirs. The pump can be used by one or two people. It is recommended for gravity-fed irrigation in rice plots at the edge of a waterbody and in areas where the height difference between the pump and the water is less than 2.5 meters. It is produced in Niger by manufacturers trained by the Nigerien agency for the promotion of Private Irrigation (ANPIP - *Agence Nigérienne de Promotion de l'Irrigation Privée*) thanks to its improved manual irrigation component. In Niger, the pump costs an estimated 90,000 FCFA.

The treadle pump was developed to draw water from a depth of up to ten meters. Pumps in this category that have yielded good results are the Ader pump developed in Tahoua, Niger, the Ciwara II pump, and the rope pump. The Ciwara II pump is produced by a company in Mali and can draw water from a depth of up to 15 m. It has two red wooden pedals, and its pump cylinder is located six meters above the water level. It is solid and heavy, and its installation is definitive. It is made in Niger by craftsmen trained by ANPIP at an estimated cost of 120,000 FCFA.

It should be noted that manual water extraction technologies such as the treadle pump, are labor intensive and can only be used to irrigate small areas. This also limits profits due to labor costs. However, compared to other pumping options, it is economical, easy to use, handle and transport.

Motor pumps

An international NGO, the French Association of Volunteers of Progress (AFVP - *Association Française des Volontaires du Progrès*), has successfully tested and disseminated the following technologies: 3.5 to 5 horsepower (hp) heat pumps (Honda, Yamaha, Robin); Indian motor pumps (Greave, Sawki); 1.4 hp Chinese motor pumps or low-power submersible pumps (Government of Niger, 2007). These have the advantage of being technically competitive thanks to the technical training also provided. However, compared to other types of pumps, they are expensive and their spare parts, which are also expensive, are not always available. Diesel water pumps are more efficient in surface water extraction. They must also be well adapted to the areas to be irrigated. Training in their maintenance is necessary and they should be used in growing high-value crops if the farming is to be profitable.

Field experiments show that operators are enthusiastic about using motor pumps. However, these pumps require a significant investment for their acquisition and their lifespan is relatively short (often less than five years). Spare parts can also be hard to find making maintenance difficult, and their fuel is not always available, especially in some remote areas. Further, motor pumps have negative climate impacts, and their service life is between one and two years. The use of motor pumps has expanded exponentially in Niger's Agadez region over the past decade. The intensification of onion cultivation, the need to develop previously marginal land, the high cost of labor, as well as support from the state and partners have all played an important role in the development of this equipment.

However, use of the motor pump also has negative consequences for producers and their environment. This pump, like any other machine, must be handled with an abundance of care. Further, fatal accidents related to carbon monoxide poisoning have been recorded, mainly in the Aïr region. In addition, the demand for groundwater has increased considerably because irrigation networks have not been adapted to existing water resources. Lastly, operating costs keep rising due to the increasing cost of fuel and maintenance.

Solar pumps

With the fall in prices of photovoltaic panels, pumping with solar energy is now a viable alternative. However, a solar pump adapted to the needs of small-scale producers is not yet available on the Nigerien market. The Sunflower solar water pump is a model that avoids complex electronic components and uses a simple piston pump which, in terms of energy, is the most efficient way to extract water. The pump is driven by a DC motor, which receives its power from a photovoltaic solar panel 80 (70 x 80 cm).

A solar irrigation system is a green, renewable energy technology that saves on fuel and electricity costs. According to 2018 data from the Regional Chamber of Agriculture (CRA - *Chambre Régionale d'Agriculture*) of Maradi, Soumarana, the purchase of fuel for irrigation represented 45 percent of the production costs of carrots and 22 percent for onions. This explains the increasing demand for the installation of solar irrigation systems for small-scale commercial farming (solar panels and submerged pumps) by Maradi producers, who can also benefit from agricultural credit and subsidies.

In 2017, about ten producers received credit from the microfinance institution, ASUSU, with a grant from the Small Irrigation Support Program (PAPI – *Programme d'Appui à la Petite Irrigation*) in Tarna for the installation of solar irrigation systems. Monitoring activities led by the CRA showed that the solar panels acquired were not installed. In the Maradi area, the field installation of solar panels requires the recruitment of a guard whose services sometimes cost more than the usual cost of buying fuel for a motor pump. One of the producers was even considering reselling his solar equipment. Nevertheless, some farmers still use their solar irrigation kits and are satisfied. During their five years of use, these kits have only experienced minor breakdowns that can be repaired by local craftsmen or by the producers themselves.

Community sites face difficulties due to their small size and management issues. In Soumarana, one of the sites covering four hectares is no longer powered by the solar irrigation system due to a failure in 2018 that has not been repaired.

California distribution network (or Zamani network)

Mechanized water distribution techniques are being developed to improve irrigation efficiency. These techniques save water and are used to irrigate large areas. The California network is the most popular technology among producers. It is a low pressure water distribution system that uses buried PVC piping (for lower costs) and COTOPLAST type plastic films produced in Cote d'Ivoire. The California network generally adapts to all sites thanks to its flexibility and low construction costs (about 1,500 FCFA per meter installed). It is crucial to find a good match between the collection flow rate of the well or borehole and that of the motor pump, as well as between the areas to be watered and the power of the motor pump (GMP). This system is recommended for irrigating slopes and reducing water losses by infiltration. It is well suited for sandy soils, and comes supplied with a motor pump or a push-pull hand pump. It can be combined with plastic foils and spray heads for water distribution.

Other advantages of the California system include the ease with which it can be put together, used and maintained. It requires the presence of local workers trained in this field. Parts are available in local markets at affordable costs, about 1,500 FCFA/meter.

Based on the review of extraction and/or retention technologies above, the water distribution system of the California network is an adaptable technology for use in crop fields. This system is applied with the aim of improving irrigation efficiency in comparison to techniques that use concrete (especially in large-scale irrigation) and earthen channels. It is also an alternative for producers with limited financial resources. This technology reduces irrigation water losses and therefore also reduces the cost of pumped water.

The California water distribution system is well suited to cultivation of vegetables, rice and arboricultural plots of 0.25 to 2 hectares. It is adopted and used throughout Niger, mainly in small village irrigated areas (PPIV–- *Petits Périmètres Irrigués Villageois*) and small-scale commercial farms (PPM - *Petits Périmètres Maraîchers*). Installation of the California network requires basic plumbing skills and local craftsmen can easily master the technique. Materials for installation are readily available. However, stray animals (if the plots are unfenced) and strong sunlight can damage the pipes.

Drip irrigation

Micro-irrigation or drip irrigation is the most effective way to grow crops in areas where water is scarce. Drip irrigation allows the distribution of water through a network of low-pressure pipes, bringing water to the immediate vicinity of crops. However, the equipment is not always accessible to small producers as it costs a lot for these farmers cultivating small plots. As a result, many farmers still use traditional irrigation techniques (manual watering) within small areas with partial water control. Few producers have sufficient means to use groundwater.

In Niger, the first micro-irrigation project was launched in the early 2000s, following a program to aggregate large community fields of five hectares at village level. In 2005, FAO established an experimental center in Indican. Plots of 1.5 ha were offered to each of the eight families identified on the site during the implementation phase. Men grew potatoes, cabbage, squash, tomatoes, onions and peppers, while women raised animals provided by FAO. Training sessions on agricultural practices and capacity building were also offered to farmers. According to a survey carried out by Agrimex in 2014, the expansion of the system was hampered by the lack of a formal framework for exchange among structures supporting micro-irrigation, as well as by a lack of external communication and institutional memory.

The low pressure drip system is recommended for Darey Gorou. The 'African vegetable gardens' project, led jointly by ICRISAT and ANPIP, distributed 900 family drip systems (FDS). These included 700 FDS of 80m^2 mainly for women and 200 units of 500m^2 for more complex commercial uses. This technology is particularly suitable for areas where water is a limiting factor. However, it requires sustained outreach to familiarize producers with methods for operating and maintaining the network and equipment.

Results from a survey conducted by the 'African vegetable gardens' project among small-scale commercial producers indicate that the average profits from a vegetable garden of 0.2 ha is about 184,000 F CFA per year when a foot pump is used. This is equivalent to 920,000 F CFA per hectare with five months of production. In comparison, rice farming yields 265,000 F CFA/ha. Small-scale commercial farming is therefore a more profitable activity although it is more risky.

Belt sprinkler system

This is a newly introduced irrigation technology in Africa south of the Sahara (SSA). It involves the generation of precipitation that mimics natural rainfall. This irrigation system is suitable for vegetable crops on boards and is popular with small-scale commercial producers.

Like the drip irrigation system, strip sprinkler systems are easy to use and operate autonomously, reducing the drudgery and time spent on irrigation. The sprinkler belts are connected to a PVC or PE pipe that is fed by a motor pump. The number of sprinkler belts depends on the pump's output. Maintenance of the spray bands is simple even when using loaded irrigation water. To clear the spray bands, the clamp at the end is removed and water runs at full flow for a few minutes through the belt. The water flushes out the materials and particles clogging the holes of the spray belt.

Installation costs are relatively low compared to other technologies. The belts have to be replaced every three to four years. The cost of acquiring 100 meters sprinkler belt falls between 10,000 FF CFA and 20,000 FF CFA in Burkina Faso and Niger.

Remote irrigation system

The remote irrigation system was developed by Nigerien inventor Abdou Mamane Kané and ranked among the top ten innovations of the year at the African Innovation Award ceremony in Abuja, Nigeria. This system allows small-scale commercial farmers to undertake remote irrigation with equipment that includes: an energy production system, a dewatering system and irrigation devices. The system allows the user to dial a short number (in the case of Niger, 140) to automatically connect to a database managed by the company Tech Innov, promoter of the initiative, which identifies the customers and automatically connects them to their vegetable garden.

Small-scale commercial growers can operate the system either by SMS or voice commands. This system therefore provides a long-term solution to the challenges facing irrigation in Africa, namely the drudgery of work and the time needed for manual irrigation. However, the system is not well-known and has not been popularized at the level of farmer organizations, because there are no data or statistics on its concrete use in the field. This can be attributed to its high cost, which is not within the reach of all producers (a unit costs 2.8 million F CFA francs or about 4,300 €).

3. METHODOLOGY

This study followed a series of steps to examine the feasibility, scalability and impacts of small-scale irrigation (SSI) technologies in Niger. The first step explored the availability of water for irrigation in Niger using remote sensing satellite data. The second step involved the identification of priority crops for SSI and their constraints based on existing practices and crop statistics. The third step estimated the feasibility of SSI across different geographic areas in Niger. In the fourth step, we estimated the potential area that could be covered by the four identified SSI systems to show the scalability of the technologies. The fifth step involved predicting the economywide ex-ante impacts of the technologies. The next sub-section describes the approach used to estimate the feasibility, scalability and ex-ante impacts of the selected technologies.

3.1 Estimating the Feasibility of Small-scale Irrigation across Space

Estimates of potential feasible areas for irrigation are available in many countries. However, these estimates vary widely from one source to another. Additionally, in many instances, they are only defined by water availability and other biophysical constraints. In this case, we estimated the SSI potential based on the method described in You et al. (2011). Unlike previous estimates of irrigation potential, this estimation method is based on biophysical and socio-economic factors using a three-step integrated, spatial method. In the first stage, geographical grids of 10 km are allocated to crops selected from a total of 20 crop groups found in Africa south of the Sahara. Allocation is based on topography and other biophysical factors of the grid. A country may only allocate a few crops based on its biophysical diversity.

The second step involves determining the runoff potential (surface water only) of each grid to predict the grid's suitability for irrigation. Depending on the availability of water and the command area, feasible areas are determined for large- or small-scale irrigation.

The third step is estimating the cost-benefit ratio of investing in water collection with a dam. This is done using the investment and operating costs obtained from existing SSI schemes and the prices and yields of the selected crops for each grid. Cost-benefit analysis makes it possible to predict the IRR (internal rate of return) of the investment in SSI in different sites. The objective of this analysis is to identify the best sites where specific technologies can be scaled up. The geographic distribution of feasible irrigation investments is then estimated based on an average investment cost of US$ 2,000/ha and US$ 80/ha directed toward operations and maintenance/management (O&M).

3.2 Estimating the Scalability of Small-scale Irrigation Technologies

The viability and adaptability of irrigation technologies was assessed using the methods described by Xie et al. (2014). Estimation involved use of a four-step approach. In the first step, the environmental and demographic suitability of a 500m geographical grid is evaluated for the four different small-scale irrigation systems identified, i.e., treadle pump, small reservoir, motor pump, and river diversion irrigation systems. The criteria for suitability are groundwater potential as determined by FAO, topography, runoff, market access, distance to surface water and population density (Xie et al., 2014).

In the second step, a Soil and Water Assessment Tool (SWAT) model is used to predict water availability and consumption, as well as crop yields at the river basin level using topography, soil type and other biophysical factors.

In the third step, a DREAM (Dynamic Research Evaluation for Management) model is used to predict the effects of SSI expansion on product prices. Three market price determination options are considered for different product groups. For vegetables and legumes, we assume that local market prices are determined at the river basin level. For peanuts, sugarcane, potatoes and sweet potatoes, we assume that prices are determined at the level of the domestic market. For maize, wheat and rice, we assume that these are internationally traded commodities with prices determined at the global level.

In the fourth step, we perform a cost-benefit analysis to estimate the optimal crop mix, irrigation expansion yield, population reached (direct and indirect beneficiaries), net incomes, exploitable areas and water consumption levels. Crop combinations and yields are estimated based on yields and prices predicted by the SWAT and DREAM models, respectively. Net revenues, exploitable areas, and water consumption levels are estimated based on investment costs, technology life spans and operating costs. Net technology yields per hectare and per 1,000 cubic meters (m^3) are calculated by dividing the annual net income by the total feasible area and total water consumption, respectively. Net returns vary across technologies, based on costs, yields and product prices.

Following these four steps, we determined the total potential feasible area for each irrigation system, the number of rural people who would benefit from these irrigation technologies, levels of water consumption and the economic returns (net value-added) that could be generated from these irrigation systems.

3.3 Estimating the Ex-ante Impacts of Irrigation Technologies

Once the potential irrigation areas for the four technologies were determined, we ran an economy-wide simulation analysis to predict the aggregate impacts of the technologies. The analysis combined a Computable General Equilibrium (CGE) model and a top-down microsimulation (MS) model to assess the social and economic effects of small-scale irrigation expansion in Niger. The CGE model is dynamic-recursive and fits within the standard Walrasian framework in which economic agents make decisions (consumption and production) according to relative prices. Local producers arbitrate between domestic and international markets (CET function) and consumers arbitrate similarly between local and imported products following Argmigton hypothesis. Household consumption is accounted for using the demand system based on Stone-Geary preferences (utility function). The labor market is segmented according to place of residence (rural or urban), education level (skilled, semi-skilled or unskilled) and gender (male or female), and there is a wage curve between these segments. Public savings adjust to finance public spending, the balance of the external current account is assumed to be fixed, and the real exchange rate adjusts.

The model's specificity lies in the treatment of irrigated land in the agricultural sector. On the production side, irrigated crops are distinguished from rain-fed crops to highlight the yield gap between the two agricultural systems. Yields from the irrigated system are higher than yields from the rain-fed system (Table 1). The production function in each system has a constant elasticity of substitution (CES) at several levels. Output from an activity is derived from combined value-added and intermediate consumption based on fixed proportions. In addition, value-added aggregates efficient labor and land, always in fixed proportions. Land productivity is assumed to be considered in the value-added function to capture the productivity gaps between irrigated and rain-fed systems. Efficient labor in turn replaces ordinary capital and aggregate labor. The latter combines various categories of work based on fixed proportions. On the demand side, perfect substitution between irrigated and rain-fed products is assumed, in other words, irrigated maize and rain-fed maize have the same market price.

Table 1: Productivity gap between irrigated and rain-fed systems by crop in 2019

Crops	Area (Ha)	Yield under rain-fed system (kg/Ha)	Yield under irrigation system (kg/Ha)	Ratio of irrigated to rain-fed system yields
Cowpeas	5,668,273	384	1,447	3.8
Sorghum	3,767,756	514	1529	3.0
Onions	35,016	24,824	34,007	1.4
Groundnuts	878,554	584	1,568	2.7
Tomatoes	14,174	16,350	25,067	1.5
Sorrel	196,928	374	1,228	3.3
Okra	136,598	796	11,829	14.9
Cassava	10,339	13,085	23,688	1.8
Maize	28,559	601	1,822	3.0
Rice	23,939	2,246	5,850	2.6
All products	**10,760,135**	**568**	**1,783**	**3.1**

Source: General Directorate of the Economy

The model is dynamic-recursive, i.e., exogenous variables change at a constant rate. Thus, labor supply increases with the rising growth rates of rural and urban populations, while total agricultural land expands at the average growth rate of the past five years. Irrigated land increases at a fixed rate imposed by the simulation scenario, and growth of rain-fed land is determined in a residual manner. Private and public final consumption increase with the population growth rate. For endogenous variables such as ordinary capital, the standard capital accumulation formula is used, that is, new investments expand the existing capital stock, net of depreciation. The allocation of new investments by sector is influenced by sector-specific costs and returns on capital.

The CGE model is calibrated using the 2013 Social Accounting Matrix (SAM) updated to 2018 using the Global Development Indicators database. To highlight irrigated land in the SAM, official country data (Tables 1 and 2) are used. This information indicates that Niger's agricultural production systems are mostly rain-fed. The total irrigated area was 183,522 Ha in 2019, representing one percent at the national level. However, the yield gaps between production systems favor irrigation, although variations are seen by crop type. For example, the productivity for cowpeas, sorghum, sorrel and maize is more than three times higher in the irrigated than the rain-fed system. For onions, groundnuts, tomatoes and cassava, the gap is 1.4, -2.7, -1.5, and 1.8, respectively. Okra has the greatest productivity gap, recorded at 14.9. In calibration of the model, these productivity gaps are used to consider the stylized facts presented above. At this stage, additional economic and demographic data, as well as elasticity parameters available through the ReSAKSS toolkit are used.

Table 2: Cultivated areas in Niger, 2019

Rain-fed area (ha)	17,869,652
Irrigated area (ha)	183,522
Irrigated area (percentage)	1.0

Source: General Directorate of Economy Niger.

The change in poverty levels is directly assessed using the MS model. Poverty is measured at the individual level and is based on micro-economic information, i.e., nationally representative household survey data. A given poverty level is associated with a certain income and its distribution among the population. Income inequality is an important determinant of poverty outcomes. The MS model captures changes in income distribution as well as measures of inequality within the population. The analysis was carried out with the MS model proposed by Fofana et al. (2019) based on the 2018 household survey in Niger.

4. RESULTS

4.1 Irrigation Water Availability in Niger

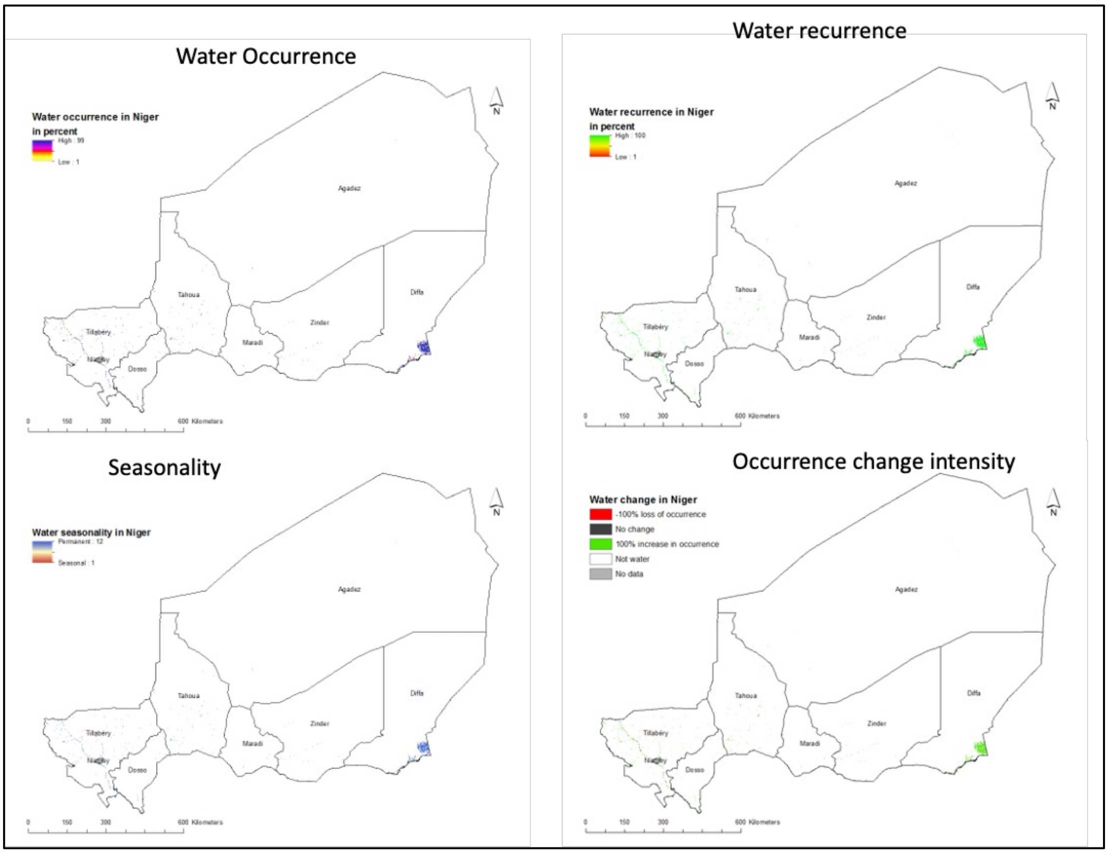
Figure 1 shows the availability of surface water in Niger using four different indicators, i.e., water occurrence, water recurrence, seasonality and occurrence change intensity. Water occurrence indicates where surface water was found between 1984 and 2020 and provides information regarding overall water dynamics. This indicator captures both the intra- and inter-annual variability and changes. Permanent water surfaces (99 percent occurrence over 37 years) are represented in dark blue, while areas where water sometimes occurs are shown in color gradations from yellow to orange. The red points are areas where water occurs infrequently.

Water recurrence is a measure of the degree of inter-annual variability in the presence of water. Recurrence specifically refers to the temporal behavior of water surfaces. This indicator describes how frequently water returned to a particular location from one year to another (expressed as a percentage). Unlike occurrence, recurrence is not systematically computed over the full span of the records, because water may not have been present during certain periods from the start to the end of the records. In Niger's recurrence maps, areas that are inundated regularly (whether seasonal or permanent) are shown in green while areas that are occasionally flooded are shown in orange.

The seasonality map provides information concerning the intra-annual behavior of water surfaces for a single year, in this case for 2020. It shows permanent and seasonal water bodies as well as the number of months when water was present during that year. Permanent water is represented in dark blue and seasonal water is shown in orange.

The occurrence change intensity map provides information on where surface water occurrence increased, decreased or remained the same in the 1984-1999 and 2000-2020 periods. Both the direction of change and its intensity are documented. Increases in water occurrence are shown in green and decreases are shown in red. Areas with no significant change in water occurrence during the 1984-2020 period are shown in black.

Figure 1: Water availability maps for Niger



Source: Authors estimation based on satellite data.

4.2 Priority Crops for Small-scale Irrigation in Niger

Priority crops are selected using the following criteria:

- Share of irrigated area where crops are grown in relation to total irrigated area.
- Share of the value of agricultural production under small-scale irrigation in relation to the total value of irrigated production.
- Share of area and production under small-scale irrigation in relation to total area under irrigation and production (large- and small-scale) of the crop.
- Geographical distribution of crops in the country and number of departments producing the crop.

Following these criteria, ten crops are identified based on the available data and the social importance of the crop. The ten crops selected are onions, tomatoes, cabbage, garlic, cassava, potatoes, wheat, maize, bell peppers and moringa. Table 3 summarizes the potential and constraints of the top five priority crops for small-scale irrigation in Niger.

Table 3: Potential and constraints of priority crops for small-scale irrigation in Niger

Crops	Opportunities	Constraints
Onions	• Niger is the largest exporter of onions in West Africa. • Second most important export product. • In 2017, onion exports generated nearly 80 billion F CFA in profits. • High demand due to its taste (Niger's typical onion, Violet de Galmi, is popular in West Africa).	• Lack of access to adequate irrigation. • Lack of sufficient quantities of quality seeds available at the right time. • Difficulties in transport and formalization of commercial transactions. • Poor control of production techniques. • Poor access to finance.
Tomato	• Its importance has increased with time. • Managed by men and women. • The national average yield is 23.36 t/ha. • Generates a gross margin of 162,600 FCFA per 1,000 m^2 (626,000 F CFA per ha).	• Vulnerable to attack by several pests and diseases that can cause losses of up to 100 percent of crops. • Volatile prices and poor market coordination. • Mainly sold as a fresh product.
Bell pepper	• Principally produced in Komadougou in the Diffa region (more than 80 percent of national production). Other areas of production include Zinder and Maradi regions. • An off-season crop, grown under irrigation. • High participation of young people and women farmers.	• Stagnant production trends. • Under-developed value chain. • Affected by parasitic weeds.
Potato	• Widely produced during the dry season. • A flexible strategy to deal with food crises and to improve incomes. • Helps reduce the migration of young men during the dry season. • Sold in cooperative markets with gross margins of 1 to 2 million FCFA per hectare.	• Lack of seeds. Niger imports these every year at a high cost. • Restricted market within the country. • Conservation of tubers. • Low remuneration of cooperatives.
Maize	• Contributes to household food security. • Mainly managed by women. • Increased production under irrigation thanks to the emergency program for irrigated crops.	• Less marketed, small quantities are sold piecemeal. • Limited access to improved seeds.

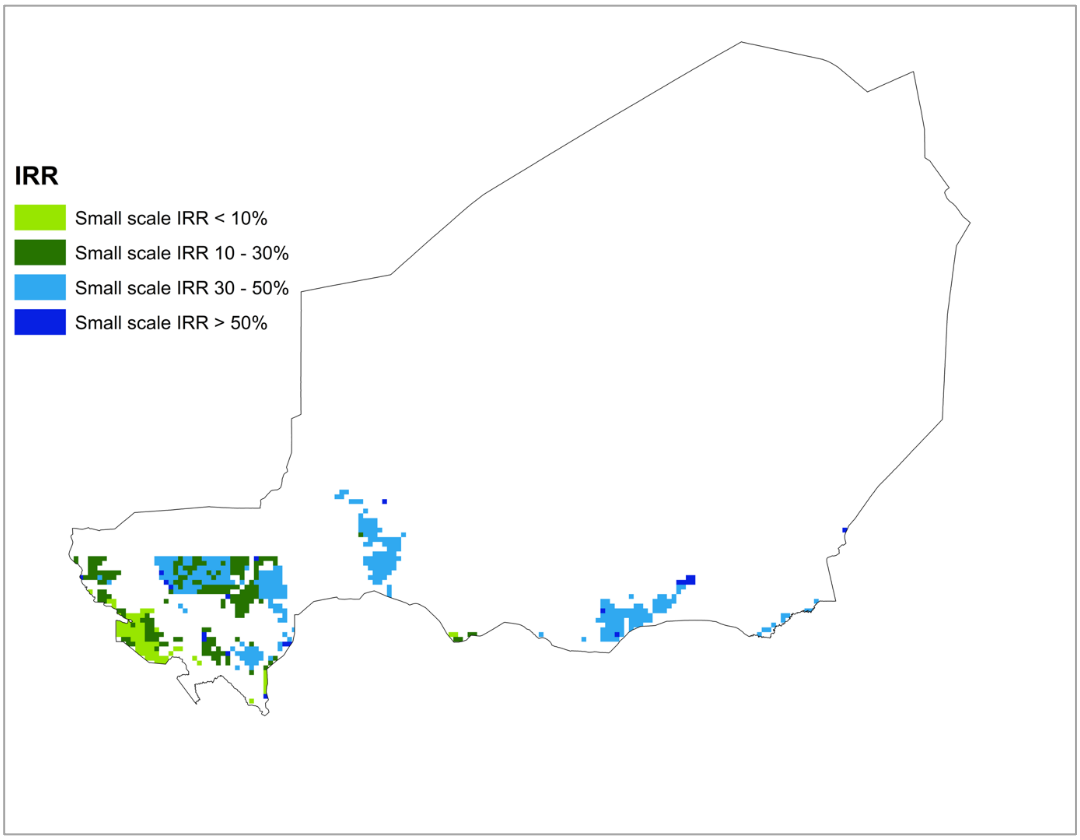
Source: Compiled from a review of national experts.

4.3 Feasibility of Small-scale Irrigation in Niger

Figure 2 shows the feasibility of small-scale irrigation across the country measured in terms of the internal rate of return (IRR). As expected, potential feasible areas are mostly located in western Niger. Most potentially feasible areas generate an IRR of 30 percent to 50 percent, followed by areas that generate an IRR of 10 percent to 30 percent. A few areas generate returns of more than 50 percent. Large areas bordering Burkina Faso are also feasible with rates of less than 10 percent.

Almost all feasible small-scale irrigation areas are found in four of Niger's seven regions, including Tillaberi and Dosso which share a large number of feasible areas. Other regions such as Tahoua and Maradi have low but profitable irrigation potential.

Figure 2: Geographical distribution and feasibility of small-scale irrigation in Niger



Source: Calculation updated based on You et al., 2011

4.4 Scalability of Small-scale Irrigation Technologies

Based on a review of studies on irrigation among African countries and the experience of Niger in particular, four types of scalable water collection and/or extraction technologies have been identified: 1) Treadle pumps; 2) Motor pumps; 3) Small reservoirs; and 4) Communal river diversions. All these systems collect or divert surface water that is then used by smallholder farmers. The adaptability (or expansion) of these technologies depends on two main factors: the amount of annual runoff water and the economic viability of the investment. In addition to these factors, the adaptability of treadle and motor pump systems depends on the availability of surface water bodies such as lakes, ponds, streams and rivers. Farmers could use pumps to extract groundwater, but this option is not considered here. Systems vary in terms of water use efficiency, environmental suitability, and economic viability. The potential for expansion of communal river diversions depends on the physical availability of small and medium-sized, non-seasonal rivers and their accessibility for the implementation of diversion works.

As Table 4 shows, in Niger, net income per hectare of land appears to be higher with treadle pumps than with motor pumps. It is also higher with small reservoirs than with communal river diversions. These options (treadle pump and small reservoir) also allow for a higher net income per unit of water consumption (compared to the motor pump and communal river diversion respectively). Among these technologies, treadle pedal pumps generate the highest net income per hectare, and communal river diversions generate the lowest net income per unit of water consumed.

These same technologies are used by a large number of people, unlike other options. Estimates indicate that 1.6 million people in rural areas could benefit from the use of treadle pump and 2 million can be reached with small reservoir irrigation systems. In addition, the total area of land irrigated using these options (treadle pump and small reservoirs) is larger than the land irrigated with the other two options. More than one hundred thousand hectares of land can be irrigated using small reservoirs, with total economic benefits of nearly US$ 70 million annually. Similarly, an additional US$ 110 million can be obtained with the use of treadle pumps in Niger.

Table 4: ScalaAbility of some small-scale irrigation technologies in Niger

Adaptability indicators	Motor pumps	Treadle pumps	Communal river diversions	Small reservoirs
Application area (thousands of ha)	136	133	6	98
Economic return (millions of US$/ year)	110	110	4	70
Rural population reached (millions of people)	1.0	1.6	0.04	2
Water consumption (billion m^3/year)	0.12	0.12	0.02	0.15
Net income (US$ per ha per year)	808.82	827.07	666.67	714.29
Net income (US$ per 100 m^3 of water)	91.67	91.67	20.00	46.67

Source: Updated calculations from Xie et al. (2014). **Note:** The total irrigation potential estimates differ from those presented in Table 2 due to the inclusion of groundwater in these estimates. These estimates also include all potential feasible areas, regardless of economic viability.

4.5 Ex-ante Impacts of Scalable Technologies

This analysis was carried out to predict the likely impacts on growth and poverty reduction of the technologies identified above, with the aim of showing the importance of small-scale irrigation at the macro-economic level.

4.5.1 Simulation Assumptions

The simulation scenarios are built on the assumption of expansion of irrigated areas with the four irrigation systems considered in this study, i.e., motor pumps, treadle pumps, small reservoirs, and communal river diversions. Information on the expansion potential by system is obtained from the results of the viability and adaptability analysis. Projections indicate that irrigated land can increase by 3 percent to 74 percent from the 2019 levels with the four irrigation systems. If expansion of irrigated land is implemented over a 10-year period, it corresponds to gradual annual increases of between 0.3 percent and 5.7 percent (Table 5). The study applies annual increases using a 10-year, recursive-dynamic CGE model.

Table 5: Estimation of the potential feasible area of irrigated land using different systems

	Potential for expansion of irrigated land (000 Ha).	Potential for expansion of irrigated land, percentage ratio of irrigated land in 2019 (%)	Annual increase over 10 years to reach potential (%)
Motor pumps	136	74	5.7
Treadle pumps	133	72	5.6
Small reservoirs	98	53	4.4
Communal river diversions	6	3	0.3

Source: Authors' computations based on the data in Table 3 and the Directorate General for Economy.

Two scenarios on the expansion of irrigated land are considered: (i) substitution of agricultural land; and, (ii) expansion of agricultural land. The assumption about agricultural land substitution is that the irrigated area expands to the detriment of the rain-fed areas with the four irrigation systems. In this case, the irrigation system is installed to supplement rainfall during periods of drought. Therefore, while the total area of cultivated land increases at a rate of 1.122 percent, the increase in irrigated land area (0.322 to 5.702 percent) slows the increase in non-irrigated land area (1.006 to 1.137 percent) compared to the baseline scenario (1.413 percent) (Table 6).

The assumption on expansion of agricultural land is that irrigation and rain-fed farming systems are complementary. In other words, the small-scale irrigation system extends agricultural activities beyond the rainy season. The cultivated area therefore expands with the four irrigation systems (1.255 to 1.27 percent) compared to baseline (1.122 percent) (Table 6).

Table 6: Area cultivated in Niger under the assumption of substitution and expansion, average annual change (percentage)

	Substitution			Expansion		
	All products	**Irrigated**	**Rain-fed**	**All products**	**Irrigated**	**Rain-fed**
Baseline	1.122	0.000	1.413	1.122	0.000	1.413
Motor pumps	1.122	5.702	1.006	1.255	5.702	1.413
Treadle pumps	1.122	5.602	1.009	1.252	5.602	1.413
Small reservoirs	1.122	4.372	1.044	1.218	4.372	1.413
Communal river diversions	1.122	0.322	1.137	1.127	0.322	1.413

Source: Simulation results according to the CGE model.

In the baseline scenario, agricultural land productivity remains relatively constant, i.e., it declines slightly at an average annual rate of 0.051 percent (Table 7). With the exception of communal river diversion systems, agricultural land productivity increases slightly (0.171 to 0.264 percent) on average annually, under the assumptions of substitution and expansion. The productivity effect is strongly related to the initial share of the irrigated area in the total cultivated area. Due to the faster expansion of the rain-fed area (with lower yields), agricultural land productivity increases at a slower rate under the assumption of expansion than under the assumption of substitution.

Table 7: Agricultural land productivity in Niger, average annual change (percentage)

	Land Substitution Assumption (%)	*Land Expansion Assumption (%)*
Baseline	-0.051	-0.051
Motor pumps	0.264	0.255
Treadle pumps	0.257	0.248
Small reservoirs	0.177	0.171
Communal river diversions	-0.037	-0.037

Source: Simulation results according to the CGE model.

4.5.2 Economy-wide Effects

The expansion of small-scale irrigation leads to the reallocation of factors in the economy with a substantial increase in irrigated crop production (Tables 8-9). Rain-fed crop production declines due to the reduction in land use under the land substitution assumption, and following the reallocation of non-land resources to irrigated crops under the land expansion assumption. However, net indirect effects are positive for other industries, including non-food crops, food processing and non-agri-food industries (Tables 8-9). In addition, the overall effects are positive for the agricultural sector and the national economy (Tables 8-9). The promotion of motor and treadle pumps for small-scale irrigation in Niger increases the annual economic growth rate by about 0.4 percentage points and the agricultural growth rate by about 0.8 percentage points.

Table 8: Increase in value-added in Niger under the scenarios of land substitution, annual average change over 10 years (percentage)

	National economy (%)	Agricultural sector (%)	Irrigated crops (%)	Rain-fed crops (%)	Non-food crops (%)	Processed food products (%)	Other industries (%)
Baseline	6.4	4.2	5.7	2.1	6.2	6.4	7.8
Motor pumps	6.8	5.0	9.2	1.5	6.7	7.0	8.0
Treadle pumps	6.8	5.0	9.2	1.6	6.7	7.0	8.0
Small reservoirs	6.7	4.8	8.5	1.7	6.6	6.9	7.9
Communal river diversions	6.4	4.2	5.9	2.1	6.3	6.4	7.8

Source: Simulation results according to the CGE model.

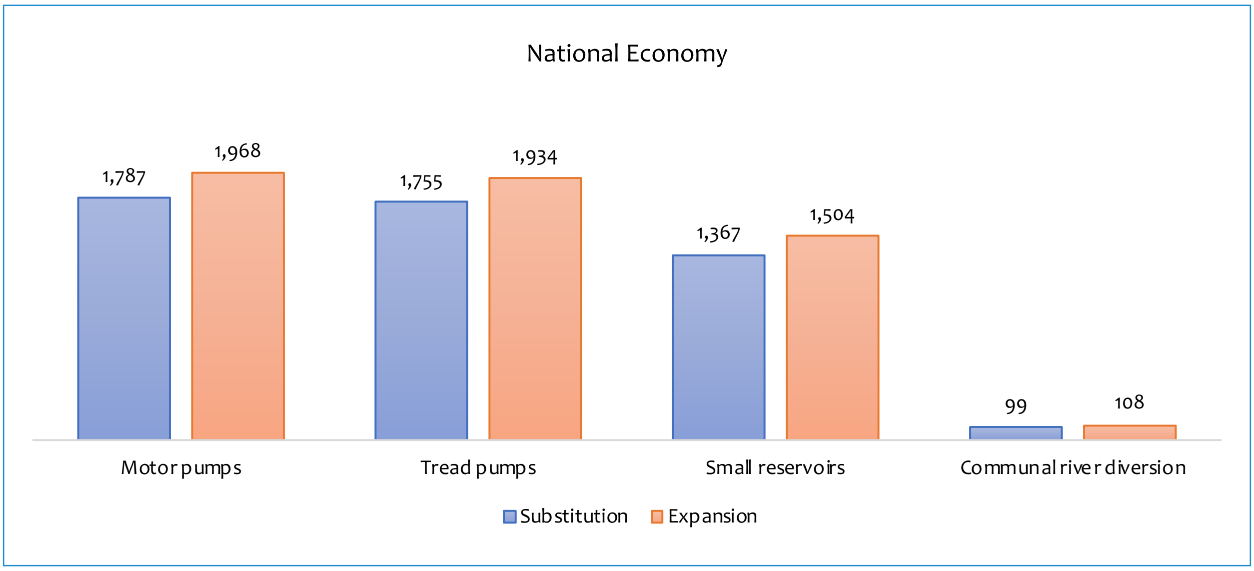
Table 9: Increase in value-added in Niger under the assumption of expansion, annual average change over 10 years (percentage)

	National economy (%)	Agricultural sector (%)	Irrigated crops (%)	Rain-fed crops (%)	Non-food crops (%)	Processed food products (%)	Other industries (%)
Baseline	6.4	4.2	5.7	2.1	6.2	6.4	7.8
Motor pumps	6.8	5.0	9.2	1.7	6.7	7.1	8.0
Treadle pumps	6.8	5.0	9.1	1.7	6.7	7.1	8.0
Small reservoirs	6.7	4.8	8.4	1.8	6.6	6.9	8.0
Communal river diversions	6,4	4.2	5.9	2.1	6.3	6.4	7.8

Source: Results of the CGE simulations.

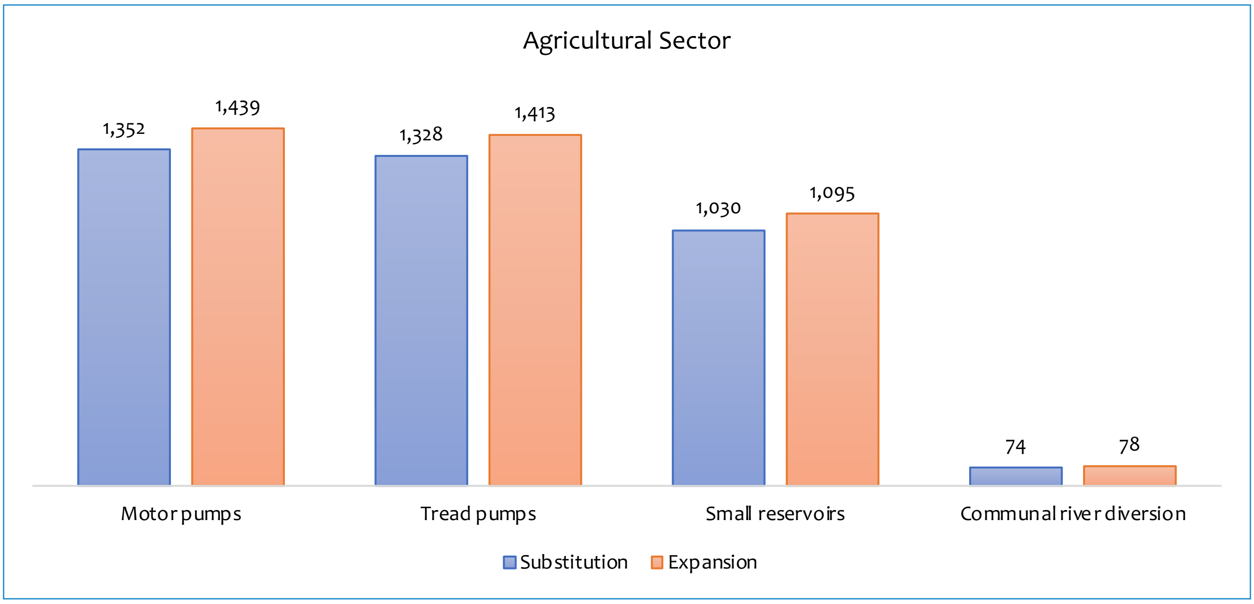
The effects of the increase in value-added remain slightly similar under the scenarios on land substitution (Table 8) and land expansion (Table 9). The expansion of irrigated areas with the first three systems (motor pumps, treadle pumps and small reservoirs) significantly increases the value-added compared to the baseline level, i.e., without irrigation expansion (Figure 3). The additional value-added would increase by 1,787 to 1,968 billion F CFA with the motor pump system and by 1,755 to 1,934 billion F CFA Francs with the treadle pump system. These systems have the greatest potential for expansion of small-scale irrigation in Niger (Table 6). The expansion of small reservoirs is expected to increase value-added to the economy by 1,367 to 1,504 billion F CFA Francs, while communal river diversions could generate between 99 and 108 billion F CFA Francs. The largest share of value-added is created by the agricultural sector which contributes about 75 percent of the total value-added (Figure 4). The agri-food and non-agri-food industries also increase their contribution to value-added (Figures 5 and 6).

Figure 3: Value-added in ten years by various irrigation systems to Niger's economy, comparison to baseline values (Billion FCFA, 2019)



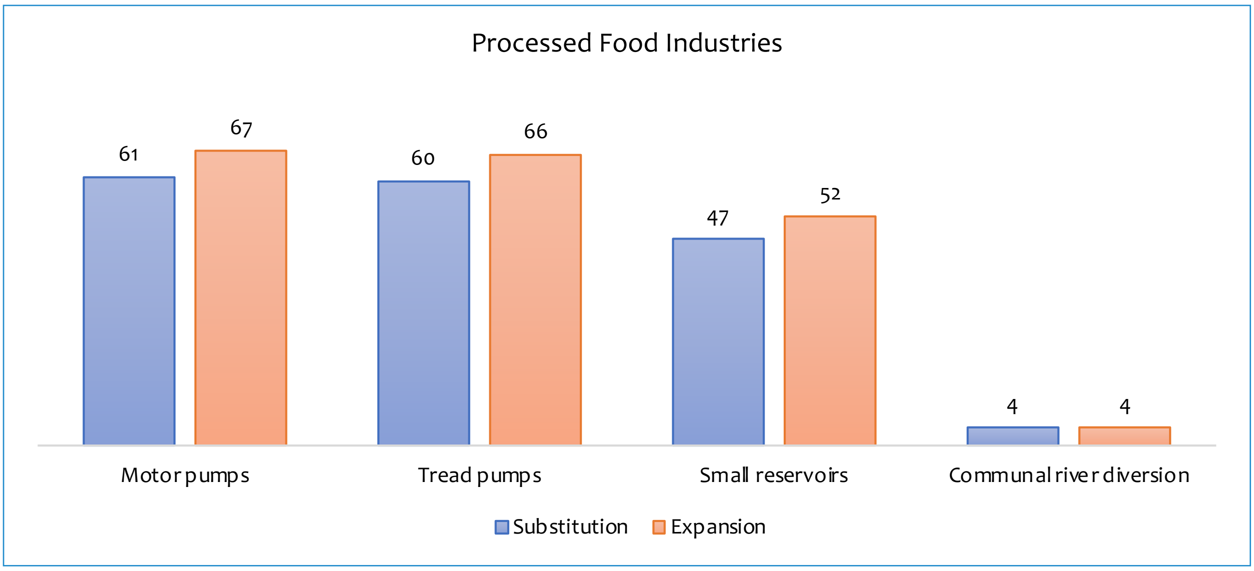
Source: Results from the CGE simulations.

Figure 4: Value-added in ten years by various irrigation systems to Niger's agricultural sector, comparison to baseline values (Billion FCFA, 2019)



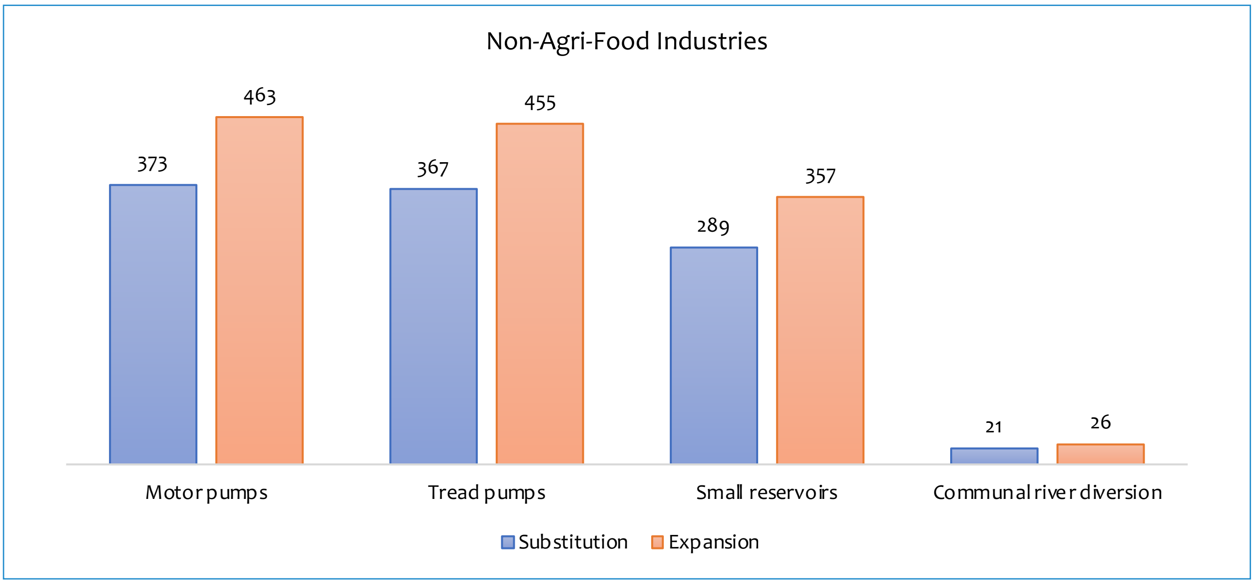
Source: Results from the CGE simulations.

Figure 5: Value-added in ten years by various irrigation systems to Niger's food processing industries, comparison to baseline values (Billion FCFA, 2019)



Source: Results from the CGE simulations.

Figure 6: Value-added in ten years by various irrigation systems to Niger's non-agri-food industries, comparison to baseline values (Billion FCFA, 2019)

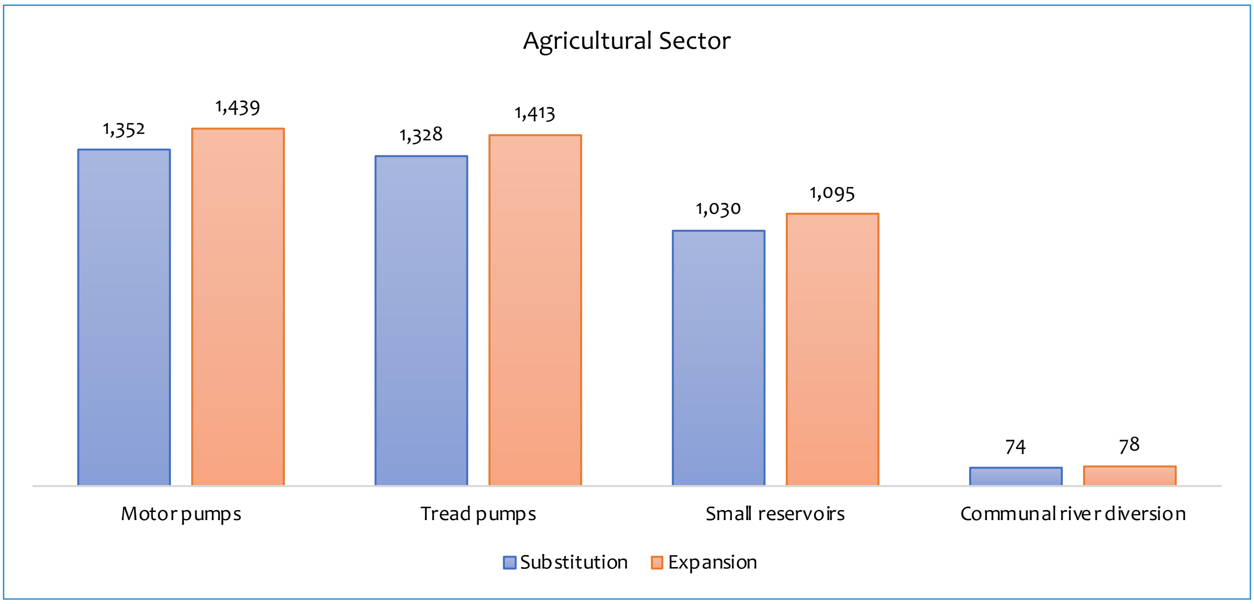


Source: Results from the CGE simulations.

4.5.3 Effects on Poverty Reduction

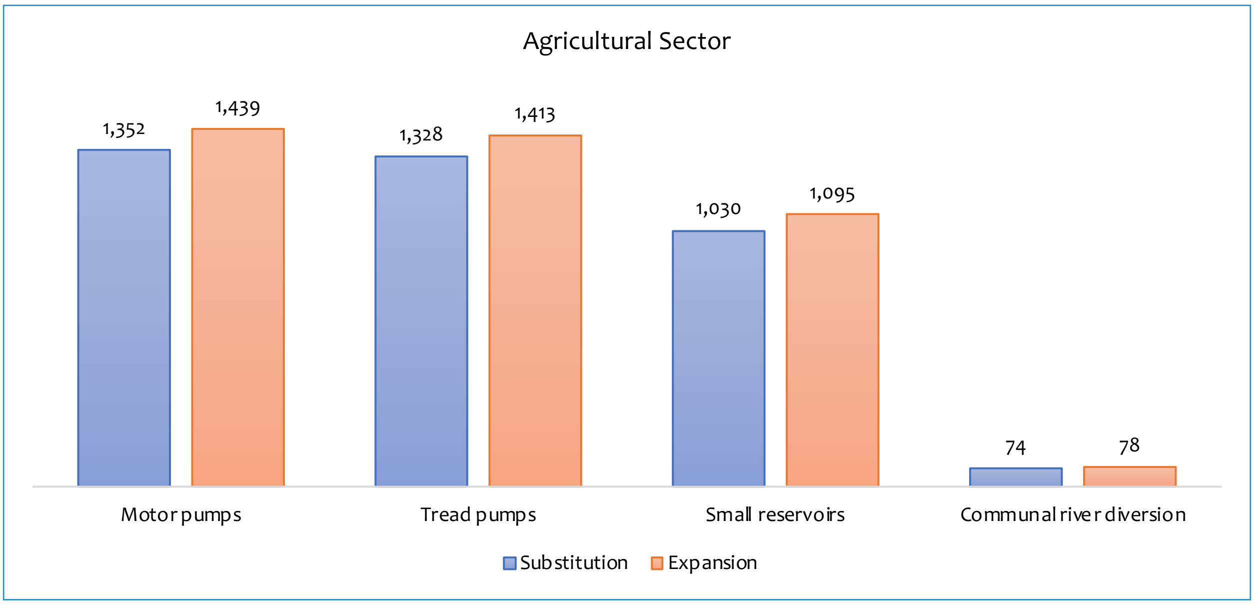
The rate of poverty reduction accelerates with the expansion of small-scale irrigation, driven by the reduction in rural poverty levels (Figures 7-9). Motor pump and treadle pump systems have the highest irrigation potential in Niger (Figure 9). Over a period of ten years, the number of people exiting poverty should increase with the extension of irrigation systems by motor pumps (203,000 to 233,000 people) and treadle pumps (199,000 to 229,000 people), in comparison to the baseline situation, i.e., without expansion of the irrigation system. The small reservoir system would lift 154,000 to 177,000 people out of poverty, while with communal river diversion the numbers would range from 11,000 to 13,000 people. Rural poverty is expected to decline faster than urban poverty, and 82-86 percent of poverty reduction through SSI expansion would be in rural areas.

Figure 7: Annual Changes in the number of poor in Niger over ten years, comparison to baseline



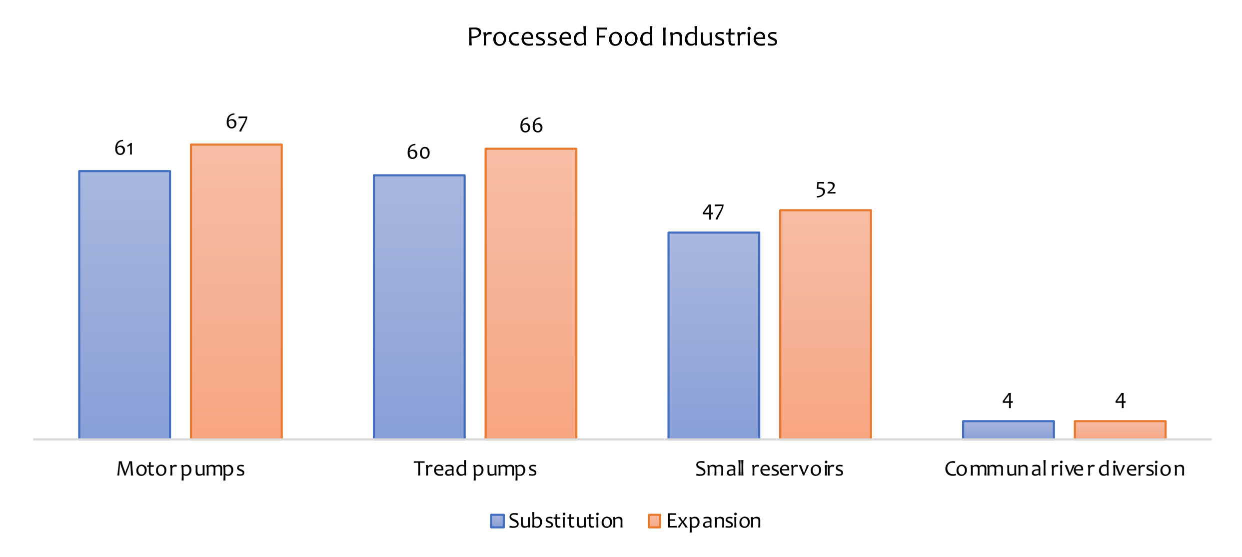
Source: Results from the CGE and MS simulations.

Figure 8: Changes in the number of poor in rural Niger over ten years, comparison to baseline



Source: Results from the CGE and MS simulations.

Figure 9: Changes in the number of poor in urban Niger over ten years, comparison to baseline



Source: Results from the CGE and MS simulations.

5. CONCLUSION AND ROADMAP

The various assessments and discussions presented above show that there is considerable interest, potential and opportunity to develop small-scale irrigation in Niger. The public and private sectors are more likely to get involved in small-scale irrigation development given the opportunities for food production. In addition to the increased market opportunities for food production and processing, several SSI technologies have the potential to significantly scale-up, expand and evolve over time. Niger's potential arable land for irrigation is significant, with an estimated 11 million hectares available for large- and small-scale irrigation.

However, the already developed area is small compared to this potential. In 2020, only one million hectares of arable land had been developed for irrigation. This is due to several factors, with the main one being an inadequate and weak irrigation development support system, which fails to provide comprehensive and ongoing regulatory and promotional support to expand irrigation investments, as well as to provide access to financial advisory services, technologies, and markets that are specific to small irrigation.

This paper examined the feasibility, scalability and ex-ante impacts of small-scale irrigation development in Niger with a focus on the expansion of four selected technologies, i.e., treadle pumps, small reservoirs, motor pumps and river diversion irrigation systems. The study revealed that there are large areas of arable land which are feasible for small-scale irrigation in Niger with an IRR as high as 50 percent. Most of these potential areas can be developed using the four SSI technologies. Motor pump and treadle pump irrigation systems are both feasible and suitable for most areas. These technologies have the potential to reverse the decline in overall agricultural growth as shown in the business-as-usual scenario and to create opportunities for growth in the sector's productivity by about 0.25 percent annually. They also improve the sector's growth rate by about 0.8 percentage points, and GDP growth rate by 0.4 percentage points in comparison to the business-as-usual scenario.

In line with these findings, a strategy for scaling-up small-scale irrigation development is critically important to reverse the declining or stagnant agricultural productivity and enhance economic growth. While focusing on the specificities of small-scale irrigation in the Sahelian context is essential, the proposed scaling-up strategy should be consistent with the main strategic reference frameworks for irrigation at the regional level. These include the Framework Document for Irrigation Development and Agricultural Water Management in Africa developed in 2020 by the African Union, and the Strategic Framework for Agricultural Water in the Sahel developed in 2017 by the Inter-State Committee for Drought Control in the Sahel.

The strategy should consist of priority actions around five operational pillars defined as support systems that need to be created or strengthened for effective and sustainable expansion of small-scale irrigation in SSA in general and in Niger in particular. The five pillars are: 1) Strengthen the technological support system, 2) Streamline the technical advisory and extension system, 3) Diversify market access interventions, 4) Expand approaches and components of the program, and 5) Develop the institutional coordination framework.

These pillars can operate in push-pull mode to build capacity and encourage farmers to adopt the technologies and best practices identified in this document. The first three pillars act as incentives, creating a favorable environment and building the capacities of farmers and other stakeholders involved in SSI development, while the last two pillars act as pull factors, encouraging farmers to invest in and maintain irrigation systems.

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AKADEMIYA 2063

Headquarters
Kicukiro/Niboye KK 341 St 22
KIGALI - RWANDA

Mailing address
P. O. Box 1855
kigali-contact@akademiya2063.org

Telephone
+250 788 318 315
+221 33 865 28 81

Website
www.akademiya2063.org

@AKADEMIYA2063
@AKADEMIYA2063
AKADEMIYA2063