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UNLOCKING THE POTENTIAL OF FARMER-LED IRRIGATION DEVELOPMENT IN CENTRAL AND NORTHERN NIGERIA: WHAT DOES IT TAKE?

Estimates from a combined biophysical-socioeconomic analysis

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The potential for profitable groundwater irrigated area development in Nigeria is 5.04 million hectares (ha), almost all of it located in the country's central and northern states. To develop this vast area, granular water budgets, financial service provision and support to grow sustainability of production will be needed.

FARMER-LED IRRIGATION: WHAT AND HOW

Increasing temperature, erratic rainfall, and other extreme events, such as floods and droughts, pose severe threats to development in Nigeria, and particularly in central and northern Nigeria where rainfall is limited, natural resources are threatened by degradation and agriculture, including livestock production, is the major economic driver. Climate change has significant adverse impacts on agricultural production and livelihoods, making the regions' poor and disadvantaged people even more vulnerable. Agricultural productivity is already affected by climate extreme events and further land expansion would increase degradation and deforestation. At the same time, the central and northern regions of the country are blessed with substantial underground water resources that have been barely tapped.

At this point, the potential of farmer-led irrigation, a system where farmers acquire the irrigation technology and access to a water source themselves, is barely exploited. What role could farmer-led, small-scale irrigation play in growing agricultural productivity, rural employment and incomes, and reducing climate stress? And what mechanisms are needed to make this happen?

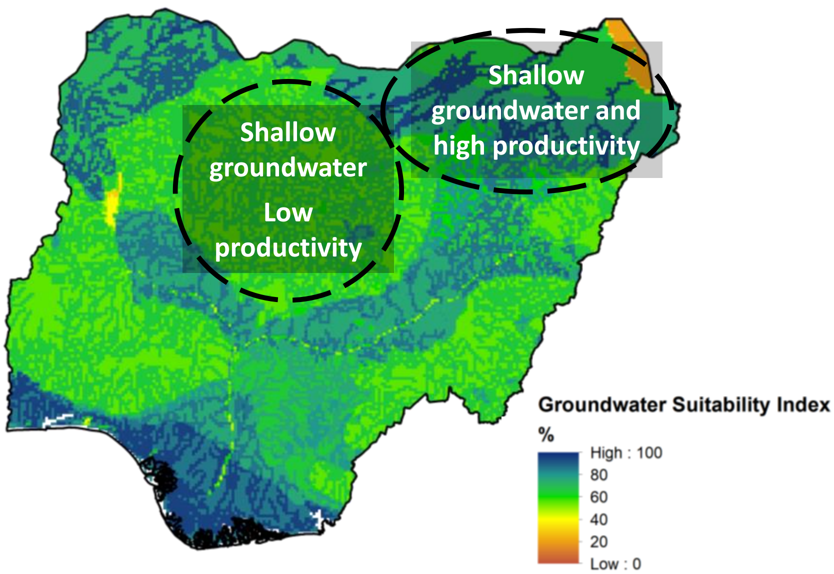
Substantial, underutilized water resources

Annual rainfall in Nigeria varies from 250 mm in the arid north to 4000 mm in the south. Most agricultural production, both for crops and livestock, is located in the drier central and northern part of the country and requires adequate access to water resources. The country's overall water resources are ample and include about 224 billion cubic meters (BCM) per year of surface and about 50 BCM per year of groundwater, much of which is unexploited, but would need to be carefully managed.

Figure 1 presents an overview of groundwater suitability in Nigeria. Two regions stand out: the north-central region with shallow groundwater at low productivity and the northeast region with shallow groundwater at high productivity. However, the lack of appropriate hydrogeological base maps, and the absence of supportive legislation and investment affects exploration, exploitation, management and monitoring of the abundant groundwater resources of the country. This makes it difficult to ensure that rapid water table declines are avoided, and fossil aquifers depleted. Poor groundwater management for irrigation could affect the estimated 60% of Nigeria's population that obtains its domestic water from groundwater sources.

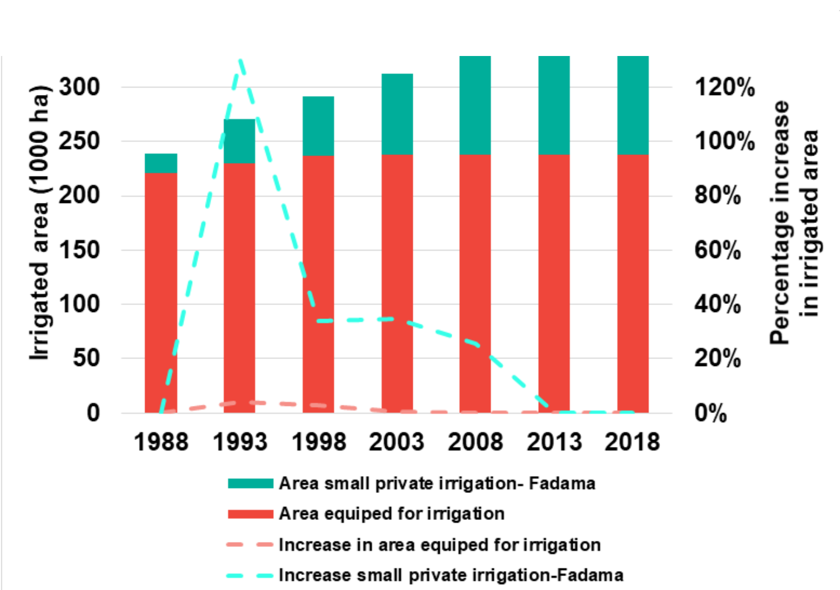
A strong foundation of community and farmer-led development

Figure 1 Groundwater irrigation suitability, Nigeria



Source: International Water Management Institute.

Figure 2 The role of FADAMA in small private irrigation



Source: Authors.

According to FAO AQUASTAT, Nigeria currently has around 1 million ha of water managed area, much of it flood recession agriculture, and about 0.33 million ha of equipped irrigated area, including about 67,000 ha of groundwater irrigation. Data for farmer-led irrigation development are difficult to come by. A 2011 Africa-wide study focusing on surface water irrigation suggested an incremental small-scale irrigation potential of 1.5 million ha for Nigeria with economic returns of 36%, compared to only 0.6 million ha for large-scale irrigation at a lower return of 18% (You et al. 2011).

Earlier investments in central and northern Nigeria have already contributed to increased farmer engagement in small, private irrigation. For example, the FADAMA project substantially increased investment by farmers in small-scale irrigation (Figure 2).

Based on an evaluation of the FADAMA III program, all irrigation activities had a positive Benefit Cost Ratio (BCR) (World Bank 2016). Farmers in areas with greater rainfall risks were more likely to use Fadama II funding to acquire irrigation pumps, and the Fadama model reduced transactions costs, such as information on where to purchase pumps and distance to markets, a key factor affecting irrigation technology acquisition (Takeshima et al. 2010a, b).

Yet, compared to the country's vast land resources—agricultural areas cover 69 million and croplands 41 million ha—irrigated area has remained small.

Solar energy opens new horizons

In this context, solar-powered groundwater irrigation is a potentially groundbreaking, disruptive technology, particularly for resource-constrained states, because this ‘clean’ energy source can ‘democratize’ energy access. This is particularly relevant as 74% of the rural population of Nigeria had no access to electricity in 2021 (IEA, IRENA, UNSD, World Bank, WHO 2023). In these rural areas, groundwater supplies are also larger and better distributed than surface supplies. In these areas, solar systems not only increase and stabilize food production during dry seasons and droughts, but also supply off-farm uses such as charging mobile phones or providing lighting.

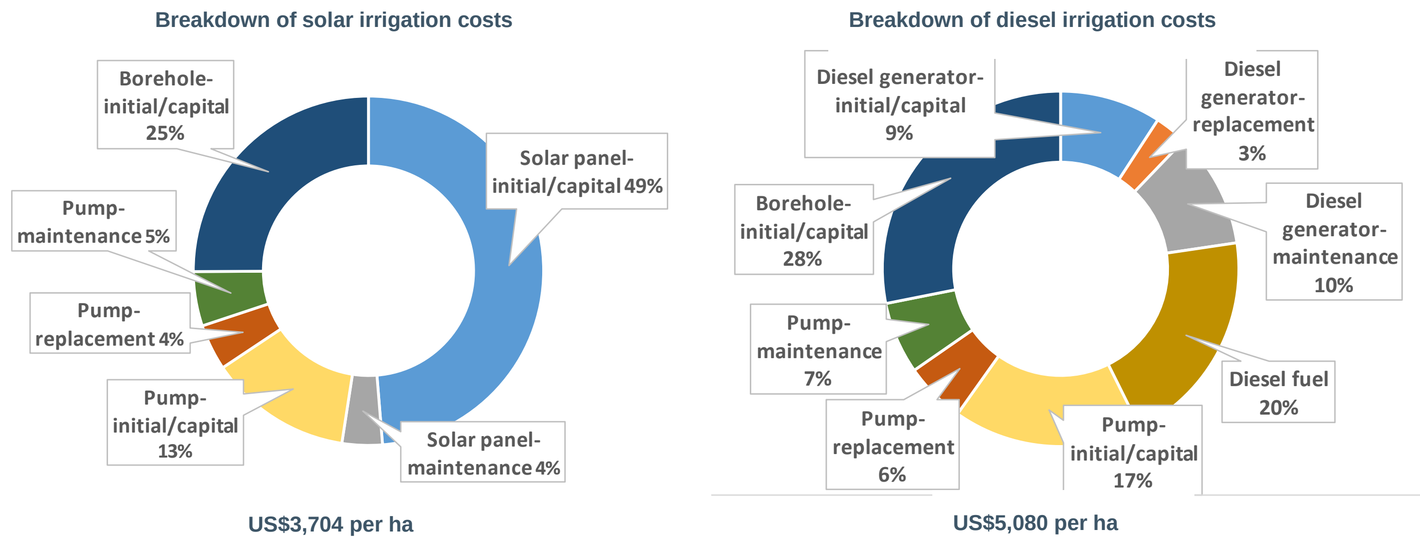
Image: Solar irrigation technology (credit: Petra Schmitter)

Solar module prices continue to drop rapidly and the solar market (on- and off-grid) is developing fast. In 2018, the off-grid appliance market in Nigeria was valued at US$ 537 million, a value that is expected to double by 2030. In Nigeria, most solar systems are sold in urban areas whereas availability of off-grid solar pumps remains low in rural areas. The latest numbers suggest sales of 3,140 small water pumps alone in the second half of 2020. Moreover, solar technologies received VAT exemptions in March of 2020. In this context, the Federal Government of Nigeria (FGN) aims to reach 5% of households with stand-alone solar technologies by 2040 and launched an ambitious plan to connect 5 million un-electrified households in the country through solar home systems (SHS) and mini-grids by 2023 (FCDO 2021).

Figure 3 describes the various cost components and shares that can make up the total cost of a diesel and a solar irrigation system for new irrigators, modelled for a medium-profitable crop rotation of rice, followed by okra, averaging values across all of Nigeria. Farmers who are already irrigating would upgrade their manual technology to mechanized irrigation, or would move from one mechanized technology, such as diesel, to another mechanized technology, such as solar. In this case, total investment costs would be much lower as borehole investments, that make up about a quarter of total cost, would already be covered. Over the lifespan of a solar groundwater system, the solar panel is the most expensive cost component, whereas for the diesel system, fuel use distributed over a longer time frame ranks second, after the borehole installation cost.

A 2021-survey of 22 suppliers of solar irrigation pumps in Nigeria as part of this study suggests that typical solar panels are rated to produce 175-360 watts at a price of ₦228.62 (US$ 0.59) per watt and have an expected mean life expectancy of 25 years. All pumps and panels sold by these suppliers were imported, but close to half included local parts to reduce importation tax. Half of the pumps were sourced from China, 18% from Germany, and 9% from Denmark. Almost all suppliers offered installation and after-sales services, including free maintenance checks, and close to three quarters offered training and after-sales care, including the provision of spare parts. More than a quarter of sellers in the survey provided financing through a tertiary partner, while 14% provided direct end-user financing, such as a pay-as-you-go option. Women accounted for about 10% of buyers.

Figure 3 Whole life cost for solar versus diesel irrigation, estimated for 1 ha, rice-okra rotation, Nigeria



Source: Authors.

GROUNDWATER-FED SMALL-SCALE IRRIGATION POTENTIAL

To better understand the potential of accelerating farmer-led irrigation in central and northern Nigeria the International Food Policy Research Institute (IFPRI) implemented a combined economic-biophysical assessment of groundwater irrigation for both solar and diesel pumps under a series of alternative assumptions regarding cropping patterns, solar panel cost, pump cost and farm size, among others.

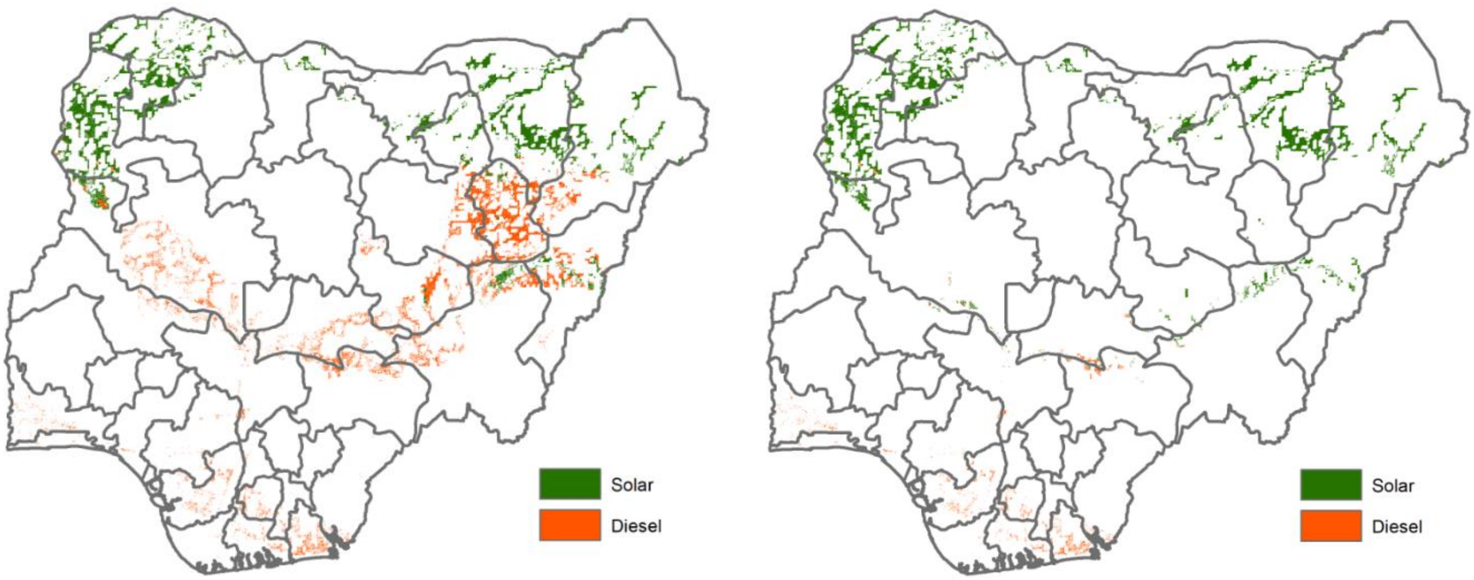
Groundwater pumping is assumed to a depth of 25 meters (m) and borehole costs are differentiated between shallow (0 to 7 m) and deeper (7.1 to 25 m) aquifer areas and groundwater suitability is considered (Figure 1). Results for a reference scenario, that assumes a farm size of 1 ha, two alternative cropping patterns (low profitability: maize and cowpea rotation, and medium profitability: rice and okra rotation), a solar panel lifespan of 15 years, an installed cost of the solar module of US$2.0/watt and a diesel fuel price of US$0.69/liter; are presented in Figure 4.

The figure shows a total profitable area for the rice and okra rotation of 5.04 million ha across Nigeria with 53% of the area contributed by solar energy. For the less profitable cropping pattern of maize and cowpea, the potential is 2.83 million ha with 91% of the potential area from solar-powered irrigation. This is a vast potential for farmer-led irrigation development—5 million ha is larger than Kaduna State—and would be the largest national irrigated area in Sub-Saharan Africa.

Moreover, almost all of the area—95% of the profitable irrigated rice-okra area and 93% of the profitable maize-cowpea area are located in Nigeria's central and northern states (see also Figure 5). Key drivers that favor solar over diesel systems are levels of solar irradiation, the cost of the solar panel, and the cropping pattern (with solar effectiveness growing with water intensity of crops), the depth of the groundwater table, and the relative costs of solar and diesel pumps. The northern, hotter and drier regions favor solar-powered groundwater irrigation over diesel irrigation.

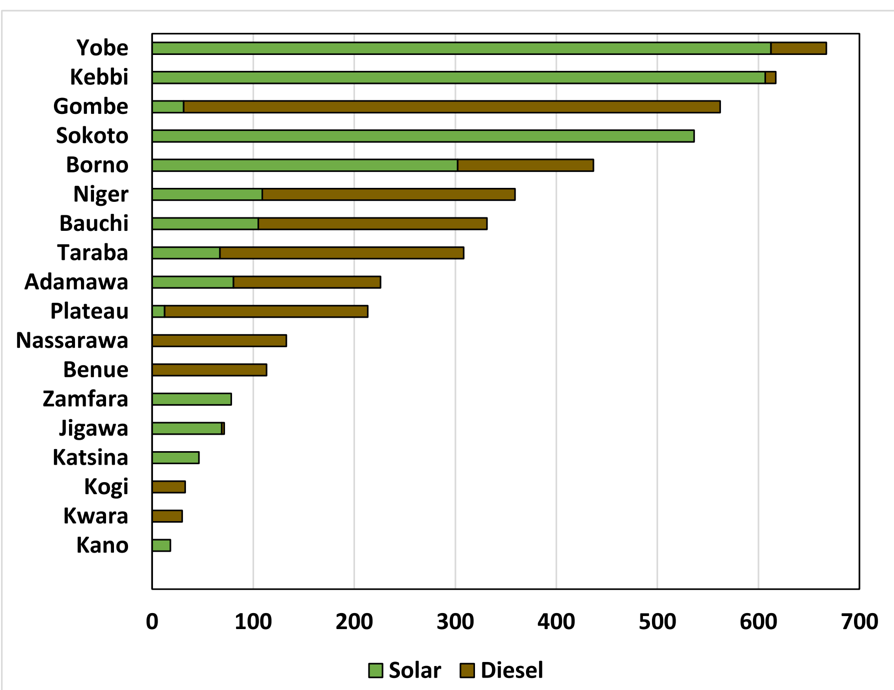
Figure 4: Profitable areas for farmer-led groundwater irrigation with solar and diesel technologies for selected cropping patterns, reference scenario

a) Rice and okra rotation **b) Maize and cowpea rotation**



Source: Authors.

Figure 5 Small-scale irrigation potential by state and technology (central and northern region), rice-okra rotation, in '000 ha, reference scenario



Source: Authors.

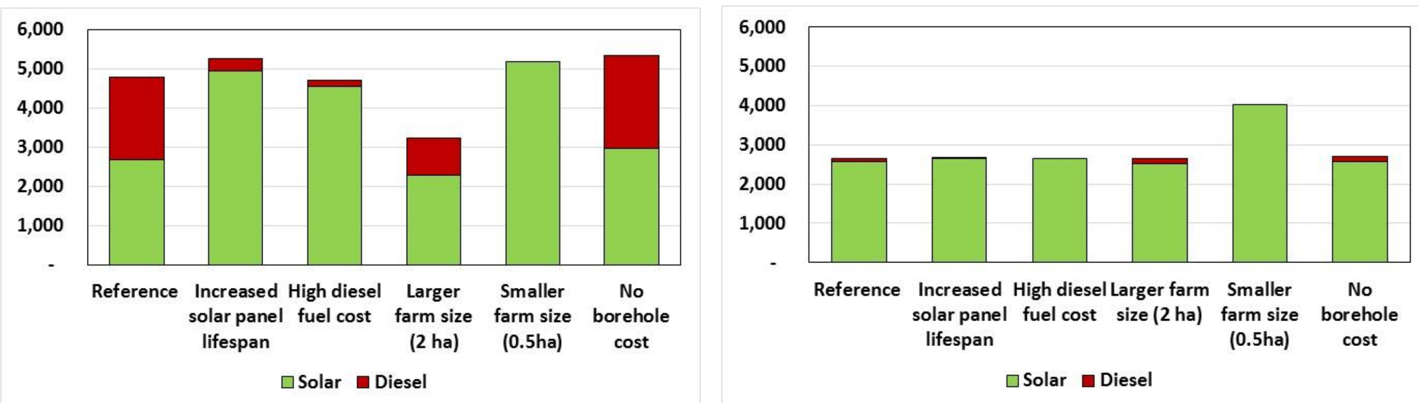
Most of the profitable areas for solar-powered irrigation are in Yobe, Kebbi and Sokoto states, where solar irradiation is largest, whereas most of the diesel pump potential is located in the central and northeastern region, such as Gombe, Niger and Bauchi states (Figure 5).

Identification of high-potential Local Government Areas (LGA) within these states requires high resolution water resource assessments and micro-watershed plans.

To better understand the sensitivity of key assumptions used in the analysis, including farm size, cost of diesel fuel as well as the lifespan of solar panels, a series of alternative scenarios were analyzed for central and northern Nigeria and summarized in Figure 6. When solar panels are more durable and well maintained, their lifespan might well increase from 15 years to 25 years (as suggested by the survey of vendors of solar pump kits). This would grow the potential irrigated area for the rice-okra rotation by 0.5 million ha and would tilt the pump mix toward solar irrigation. For the less profitable maize-cowpea rotation, the increase would be much smaller, at 9,000 ha, in part because solar is already the dominant technology for this rotation.

Figure 6 Small-scale irrigation potential, alternative assumptions for key variables, central and northern Nigeria, in '000 hectares

a) Rice and okra rotation **b) Maize and cowpea rotation**



Source: Authors.

Results are somewhat similar if diesel fuel prices increase from US$0.69 to US$1.00 per liter. This would dramatically shrink the profitability of diesel pump irrigation, by 1.9 million ha, while solar pump irrigation would grow, but not fully replace the loss of diesel pump irrigated area. The result would be a small decline in farmer-led irrigation development of 77,000 ha. For the maize-cowpea rotation, similar, but much smaller shifts would occur, essentially leaving the irrigated area unchanged.

To determine the impact of farm size, irrigation of a 2-ha farm with a single pump and borehole as well as irrigation of a 0.5 ha farm with a single pump and borehole are compared to the reference farm size of 1 ha. Irrigation of 2 ha yields a smaller total profitable irrigated area size of 3.2 million ha for the rice-okra rotation in central and northern Nigeria because at that larger size, farmers would need to install a larger and thus more expensive pump set to meet the higher energy requirement due to the increased drawdown in the borehole. If, on the other hand, only 0.5 ha are irrigated with a motorized pump, irrigated area could grow to 5.2 million and 4.0 million ha under the rice-okra rotation and maize-cowpea rotation, respectively. For this farm size, solar irrigation is more profitable than diesel pumps as farmers are assumed to self-install the system at a lower cost of US$1.2/watt, as soft costs were excluded. An analysis of secondary household survey data finds that in the central and northern region of Nigeria, 67% of farms in areas with irrigation suitability are large (2 ha or more), whereas areas without suitability tend to be smaller. Provisions should be made to ensure that farmers with smaller landholdings are not excluded from irrigation development.

Finally, a "no-borehole-cost" scenario is included in the analysis to represent a situation where borehole development cost is a 'sunk' cost, already covered by a prior investment. Compared to the reference scenario, the profitable areas under solar and diesel irrigation increase by 0.28 million and 0.25 million ha for the rice-okra rotation, while areas barely change under the less profitable maize-cowpea rotation.

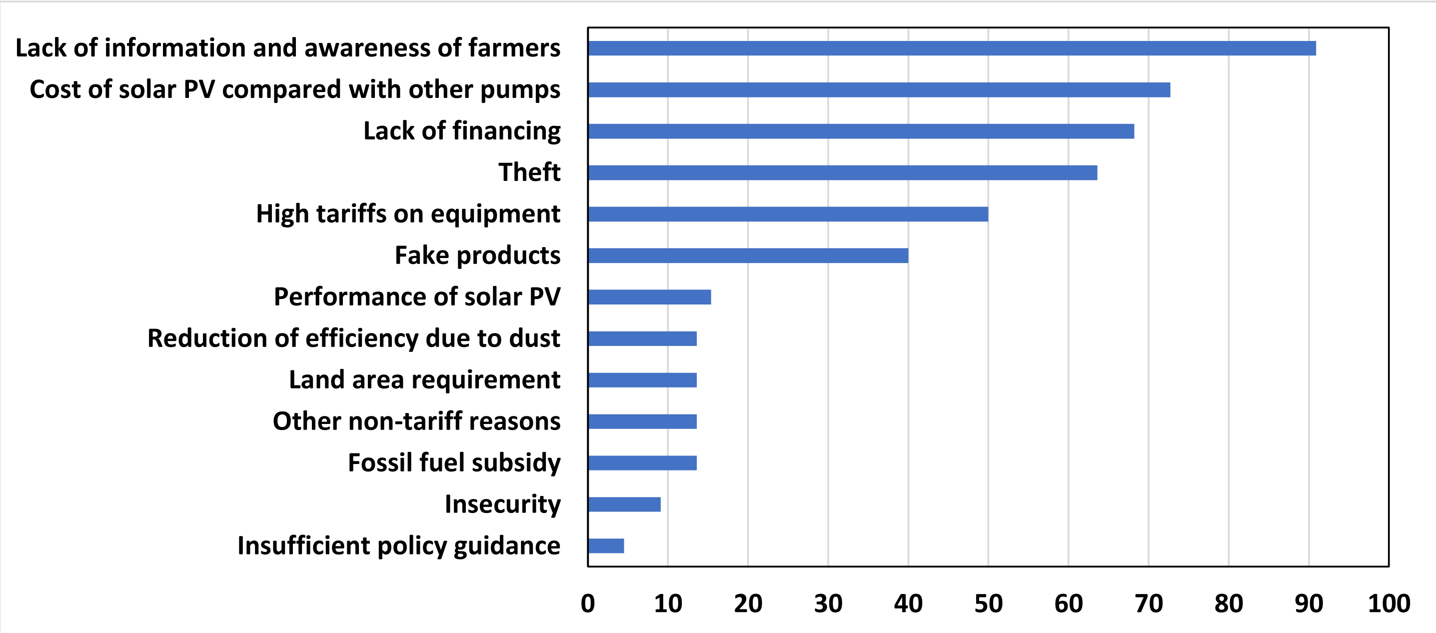
GROUNDWATER-FED SOLAR IRRIGATION IN NIGERIA's CENTRAL AND NORTHERN REGIONS: WHAT DOES IT TAKE?

A view from the field

When asked what it would take to grow the solar irrigation market in northern Nigeria, respondents to a recent survey of solar irrigation kit vendors in Nigeria revealed the following: The majority of solar system suppliers (68%) are ready to expand into more remote, northern Nigeria, but at a cost. They estimate a need for surcharges equivalent to up to ₦407 (US$1.05) per watt solar PV for the northeastern region, up to ₦331 (US$0.86) per watt solar PV for the northwestern region, and up to ₦277 (US$0.2) per watt solar PV for the northcentral region to address transportation and potential insecurity challenges linked to the delivery, installation, and after-care of the solar system.

Figure 7 presents barriers to the expansion of solar irrigation systems in the central and northern regions of the country identified by solar irrigation system vendors. The vendors believe that lack of information and awareness of farmers are the largest barriers to more rapid uptake of solar systems in these regions. The second and third reasons are interlinked: the vendors note the need for high upfront cost for solar systems as compared to other pumps, such as diesel, where the cost is more distributed over time (Figure 3). Linked with the high cost is the lack of suitable finance options that would allow farmers to purchase solar systems without high up-front investment. Other barriers identified by the vendors relate to tariffs—which is being addressed by including local materials—and the existence of fake products in the market that are being sold as quality solar pumps but are not operational or operate at lower quality.

Figure 7 Barriers to the expansion of solar irrigation systems in central and northern Nigeria



Source: Authors.

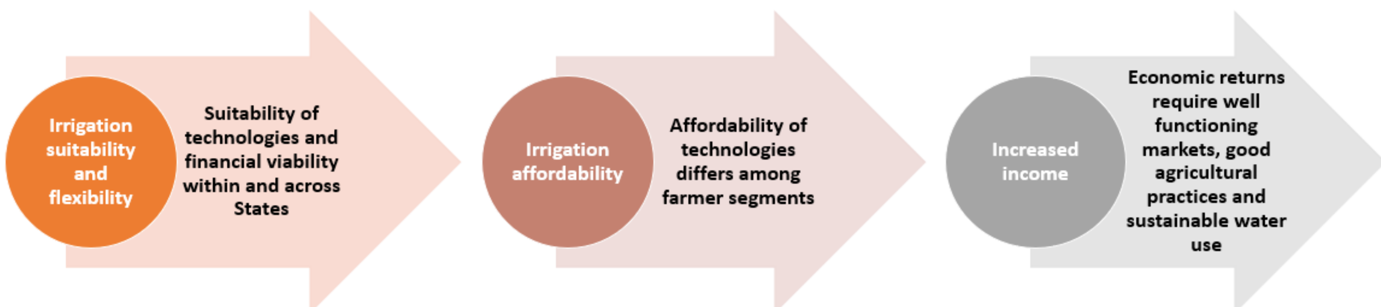
An analysis of household survey data suggests that it will be more challenging to reach smaller farms with advanced irrigation technologies. A 2019 household survey found that only 11%, 13% and 14% of households in selected LGAs in the northeastern, northcentral and northwestern region had access to formal credit. The same survey found high access to mobile phones in all three regions (above 90%), but low access to mobile internet, where information on solar irrigation pumps could be obtained. Mobile internet was used by 29% of farmers in the northwest region, 36% in the northeastern region and 54% in the northcentral region. Among LGAs in the central and northern regions, those with irrigation suitability had overall poorer access to extension, credit and internet than LGAs without irrigation suitability. On the other hand, areas with irrigation suitability had overall better market access and higher input use (fertilizers, manure and animal traction).

Relatively lower literacy levels in some states with high potential for farmer-led irrigation development, such as Kebbi, could also affect uptake of solar irrigation technologies, and could particularly affect awareness and knowledge of the technology. Among LGAs in the region, those with small-scale irrigation suitability had significantly less education than those without suitability.

Given the overall high access to mobile phones, financial services provided via these digital tools could be a viable option. Capacity building and support to solar systems could also be provided using mobile phones, for example, via SMS messages.

To address these concerns a three-pronged approach is suggested (Figure 8): Step 1 would develop a more granular assessment of water resources, crop rotations, and technologies and their financial viability within and across states to provide farmers with a suit of irrigation technology-crop value chain investment options. The analysis would also identify options for strengthening institutions and monitoring to support sustainable groundwater development.

Figure 8 Unlocking the barriers to the expansion of solar-powered irrigation in central and northern Nigeria



Source: Authors.

Step 2 would focus on enhancing farmers' access and use of information on irrigation practices, technologies and services, as well as on credit and extension, and agricultural markets through a market-based approach stimulating the private sector to serve different farmer segments in underserved markets.

The third and final step would strengthen the enabling environment and stimulate innovations around good agricultural practices and sustainable water use to ensure that the calculated rates of returns can be achieved over the 15 to 20 years of the lifespan of solar systems, and beyond.

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