TECHNICAL BRIEF

Mapping the suitability of solar energy-based irrigation pumps in Ethiopia

Background


Photo: Desalegne Tadesse/IWMI

In recent years, the International Water Management Institute (IWMI) has worked to improve food security, nutrition and livelihoods in rural communities in Ethiopia by increasing the value and effectiveness of agricultural water management through small-scale irrigation. However, while the potential to benefit from small-scale irrigation appears significant, it is constrained by access to the energy sources needed to pump water and the limited opportunities for gravity-fed small-scale irrigation systems. Electricity is rarely available to farmers on small, dispersed plots and high fuel costs mean that smallholder farmers cannot rely on diesel or petrol pumps for lifting surface water and shallow groundwater.

Building on this, a recent IWMI study determined that solar-powered irrigation pumps offer an inexpensive and effective alternative to electric and fuel-based pumps, enabling farmers to overcome energy-related access and cost constraints to expanding irrigation. The technology also reduces greenhouse gas emissions and is, therefore, considered a climate-smart technology. To ensure the feasibility of solar-powered irrigation, researchers also tested a new methodology for mapping the suitability of solar irrigation throughout Ethiopia.

Methodology

Any action to promote investment in solar-powered irrigation needs to consider a number of interrelated components. These include suitability mapping (biophysical factors, water availability, infrastructure); environmental sustainability; institutional, policy and regulatory context; finance mechanisms; technology supply chain; and economic sustainability. While any of these components can influence the decision of potential investors to support solar irrigation enterprises, biophysical suitability is by far the most important. If an enterprise is to succeed, it must have access to sufficient resources (e.g., solar energy, access to land and water resources, physical and market infrastructure, such as roads and marketplaces). Understanding the suitability of an area for solar irrigation technology also helps investors to estimate potential market size and boundaries.

The first step in suitability mapping was to identify the variables that are likely to constrain solar pump-based irrigation. The IWMI study focused on smallholder farming. Therefore, researchers based the analysis on solar pumps that were small and reasonably priced. Any areas requiring extraction of water from large boreholes or large capital investments would not be suitable for solar-powered irrigation in a smallholder context. Likewise, protected zones, forests, areas with low groundwater storage or inadequate irradiation, and slopes higher than 8% are not suitable for irrigation (areas with steep slopes are prone to erosion and may not support gravitational irrigation).

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The study then examined five scenarios to assess the suitability of solar-powered technology for pumping groundwater and/or surface water (Table 1). Scenarios 1 and 2 envisaged solar-powered irrigation using groundwater at very shallow (0-7 m) and shallow (0-25 m) levels, respectively. Scenario 3 was based on the proximity to rivers and small reservoirs. Scenario 4 represented the use of both surface water and groundwater resources, with scenario 4a including groundwater up to a depth of 7 m and Scenario 4b including groundwater up to a depth of 25 m.

To identify suitable areas for solar pump-based irrigation, researchers drew on a number of data sources with information on irradiation, slope, distance to rivers and reservoirs, groundwater depth and storage, aquifer productivity and distance to towns. The data underpinning the exercise came from national and international open source maps and were supplemented by ground-truthing data where available.

Researchers calculated the values required to qualify each of the variables as very highly suitable, highly suitable, moderately suitable, less suitable, least suitable and not suitable (constraint). For example, if an area was located within 50 meters (m) of a river, it was considered very highly suitable in terms of that variable; more than 300 m was considered least suitable. Once the variables were mapped and prioritized, researchers then assigned a weighted priority to each of the remaining variables in each scenario. The most suitable locations for solar pump-based irrigation in the context of each scenario were identified by merging all of the maps together (Figure 1). An important benefit of the suitability mapping methodology is that it allows investors to assign their own weightings, based on their circumstances and priorities.

Table 1. Variables included in the multi-criteria model based on five different scenarios.

	Groundwater		Surface water	Groundwater and surface water	
Data	Scenario 1	Scenario 2	Scenario 3	Scenario 4a	Scenario 4b
Solar irradiation (KWh m^{-2})	✓	✓	✓	✓	✓
Slope (%)	✓	✓	✓	✓	✓
Distance to roads (m)[a]	✓	✓	✓	✓	✓
Groundwater depth (0-7 m) I		✓		✓	
Groundwater depth (0-7, 7.1-25 m) II	✓				✓
Aquifer productivity (liters/second)	✓	✓		✓	✓
Groundwater storage (mm)	✓	✓		✓	✓
Proximity to river (m)			✓	✓	✓
Proximity to small reservoirs			✓	✓	✓
Proximity to town (population-dependent)[b]	✓	✓	✓	✓	✓

Source: Schmitter et al. 2018.

Notes: [a] Distance to roads is a proxy for market access.

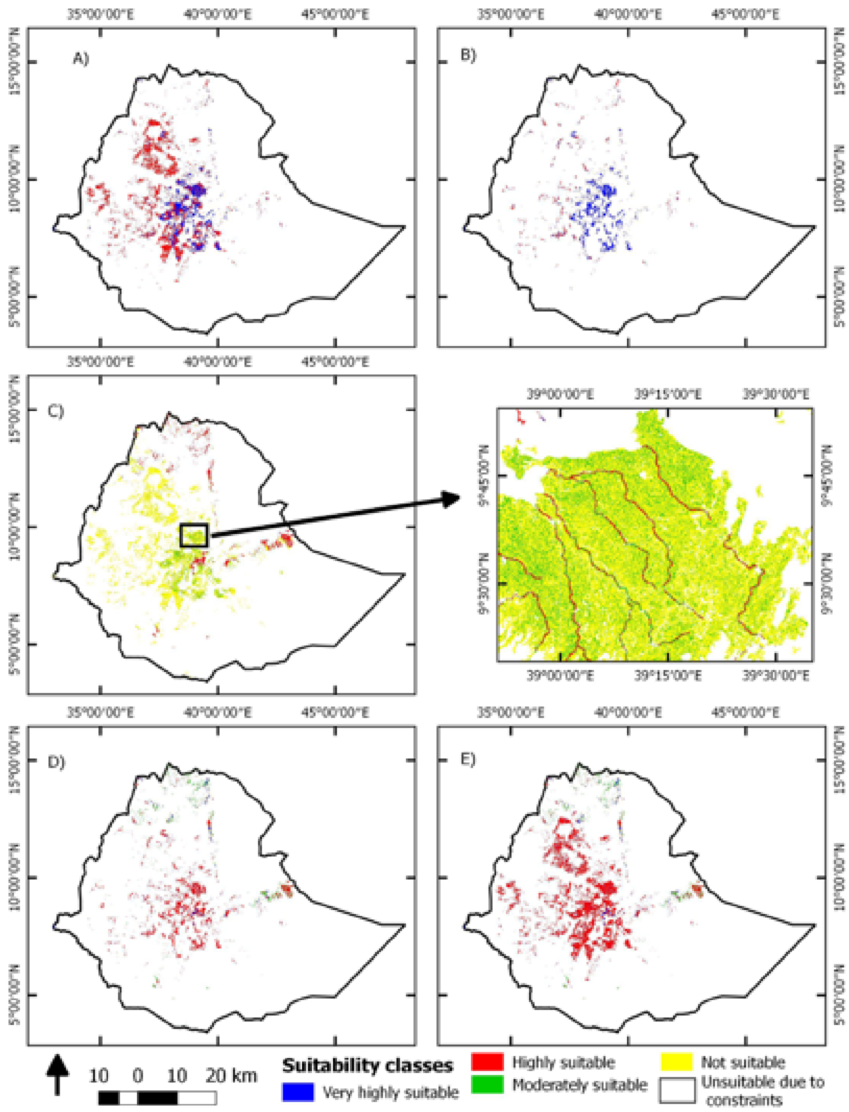
[b] This is a proxy for market access.

Findings

Depending on the water source and the technical specifications of the solar pump (i.e., size of the suction heads), the suitable area for solar pump-based irrigation in Ethiopia ranges from 1.1 million hectares (Mha) (under Scenario 3) to 6.3 Mha (under Scenario 1). Combining surface water and groundwater resources (under Scenario 4b) could increase the suitable area to 6.8 Mha (Table 2). The Oromia and Amhara regions have the largest areas suitable for solar-pump based irrigation (under all scenarios).

Comparing the suitable area under Scenario 4b with current land use indicated that solar pumps could be suitable for use on 96 Mha (9%) of the irrigated land in Ethiopia. Furthermore, if compared to current rainfed land use, solar pumps could provide access to irrigation for 3.7 Mha.

Figure 1. Suitability scenario maps. A) Scenario 1, B) Scenario 2, C) Scenario 3, D) Scenario 4a, and E) Scenario 4b.



Source: Schmitter et al. 2018.

Table 2. Potential suitable area (x 1,000 ha) for solar water-lifting devices in various regions in Ethiopia.

Region	Area (1,000 ha)				
	Scenario 1	Scenario 2	Scenario 3	Scenario 4a	Scenario 4b
Addis Ababa	2	0.6	0.2	0.7	2
Afar	8	8	2	8	8
Amhara	1,776	371	202	446	1,834
Beneshangul Gumuz	21	5	0.5	5	21
Gambella	16	8	0.4	9	16
Harar	0.4	0.4	0.8	0.7	0.7
Oromia	3,337	1,443	463	1,716	3,569
SNNPR[1]	1,077	282	41	298	1,087
Somali	10	8	154	125	125
Tigray	57	51	272	143	147
Total	6,304	2,177	1,136	2,751	6,810

Source: Schmitter et al. 2018.

Note: [1] SNNPR – Southern Nations, Nationalities, and People's Region.

Conclusions

Suitability mapping can support planning and investments to target areas for up-scaling solar pump-based irrigation, and additional refinements will only make it more reliable and relevant in the future. For example, while the suitability mapping reviewed the potential environmental consequences of solar pump-based irrigation, it did not include an in-depth environmental impact assessment. We need to know more about the environmental impacts of using solar pumps in irrigation and the potential for sustainable intensification. Some people argue that solar pumps, while lowering emissions, could lead to over-extraction of groundwater resources. Data and analysis are needed to incorporate such environmental implications and additional monitoring is required, for example, on climate variability, groundwater recharge rates and impacts from up-scaling at landscape scale. Combining the solar pump suitability maps with soil and water quality information would enable an assessment of the overall environmental sustainability of solar pump-based irrigation. The environmental impact of solar pump use is likely to be influenced by institutions, regulations and policies, and these aspects also need to be understood.

The suitability mapping exercise should also consider variables such as the implications of market proximity for cost and product prices; crop types; multiple cropping seasons with variable yields and prices; different financing mechanisms; and land availability and tenure systems. Analysis of gender-disaggregated data is needed to assess whether solar pumps favor women farmers more than men, or offer them greater benefits than other irrigation technologies.

Development donors and nongovernmental organizations, as well as some private sector actors, have piloted projects to develop solar pump markets in a number of sub-Saharan African countries. With the growing interest in irrigation expansion for smallholders in the region, suitability mapping can help to ensure that such programs target the right people, in the right places and with the right technologies.

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