Last Mile Energy Access for Productive Energy Use in Agriculture in Sub-Saharan Africa – What and Where is the Potential?

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Introduction

Sub-Saharan Africa has long been beset with food insecurity. Agriculture in the region is predominantly rainfed, which makes the sector highly vulnerable to climate variability. Irrigation is considered as a promising option to boost agricultural production and enhance agricultural resilience. At the same time, Sub-Saharan African countries also suffer from energy poverty. Lack of access to energy services limits the expansion of irrigated agriculture. A joint irrigation-energy planning framework is developed to estimate how much of the economic potential irrigated area could be powered with standalone solar photovoltaic (PV) energy. The modeling framework first compares the costs of motorized irrigation technology under solar and alternative energy solutions (e.g. diesel). The information generated from the comparative analysis informs power source selection in a model that simulates future pathways of irrigation expansion subject to water availability and market opportunities for irrigated crops. We present the joint irrigation-energy planning framework and a first set of results focusing on groundwater-fed irrigation in Sub-Saharan Africa.

Methods

Cost comparison of standalone solar PV and diesel irrigation water pumping

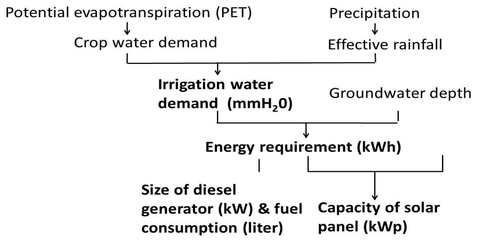
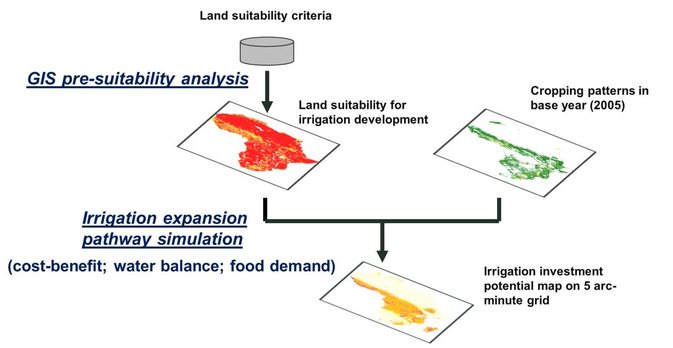


Figure 1 Calculation procedures for cost comparison of off-grid solar PV and diesel water pumping systems for groundwater-fed irrigation

Table 1 Key input data

Data type	Source
Climate	CRU
Solar insolation	PVGIS
Groundwater depth	BGS
Cropland extent	IIASA/IFPRI
Diesel fuel prices	GIZ/World Bank

Integrated modeling for strategic irrigation planning analysis

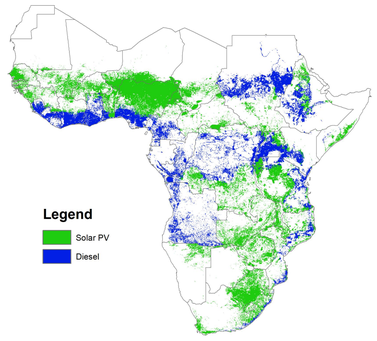


- Combined use of GIS land suitability and hydrologic & crop simulation tools: the GIS tool and multiple environmental criteria are used to score land suitability for irrigation development; the potential yields of irrigated crops, irrigation water demand, and sustainable yields of aquifers are estimated using hydrological and crop simulation techniques.
- Explicit modeling of crop mix change induced by irrigation development on a 5 arc-minute grid: likelihood of irrigation adoption is linked to the environmental suitability; irrigation expansion is constrained by water resources availability, economic costs & benefits or market potential of irrigated crops.
- Selection of energy solution: more cost-effective irrigation technology (solar PV or diesel pumping) is selected at pixel level once decision on irrigation adoption is made.

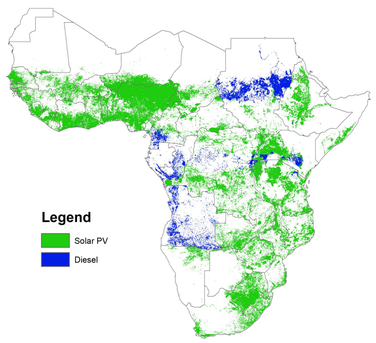
Results

Relative cost effectiveness of irrigation water pumping under two off-grid energy solutions for selected crops[1]

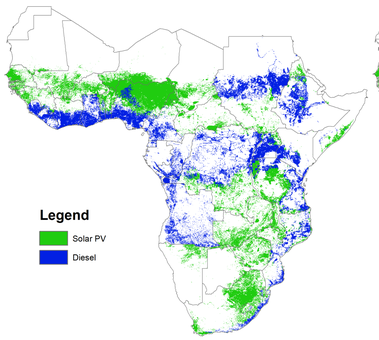
(a) Maize



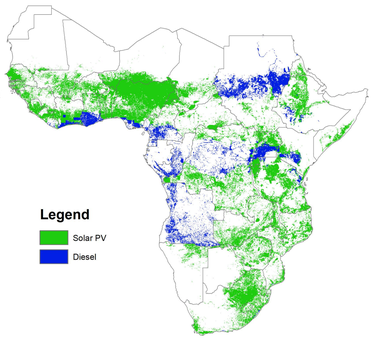
(b) Rice



(c) Wheat



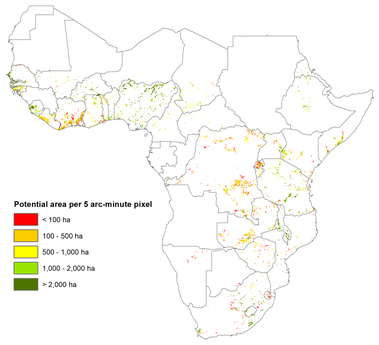
(d) Vegetables



1. Madagascar is not included in the analysis due to lack of groundwater depth data

Potential of expanding groundwater-fed irrigation by 2030

(a) Solar PV



(b) Diesel

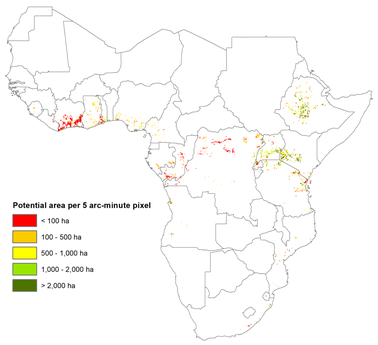


Figure 3 Top countries with large groundwater-fed irrigation development potential in Sub-Saharan Africa

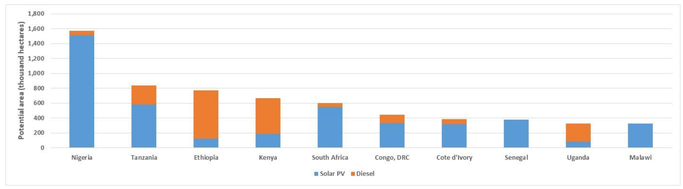


Table 2 Groundwater-fed irrigation development potential by energy source and by region

	Eastern Africa	Western Africa	Central Africa	Southern Africa	Total
Solar PV	1.2	3.3	0.5	1.4	6.4
Diesel	1.6	0.3	0.2	0.1	2.2
Total	2.8	3.6	0.7	1.5	8.6

Conclusions

- In cost comparison analysis, we map the relative cost effectiveness of two off-grid energy solutions for pumping groundwater for irrigation under a number of "if-then" scenarios. The analysis shows that there is large potential to use solar PV as an energy source for groundwater irrigation in Sub-Saharan Africa. On the other hand, the cost effectiveness of solar irrigation relative to diesel irrigation varies not only by location but also by crop, which highlights the complexity of decision-making around energy source and irrigation technologies in the region.
- Using an integrated modeling approach and information from the cost comparison analysis, we estimate that the development potential of groundwater-fed irrigation in Sub-Saharan Africa over the next decade is about 8.6 million hectares, 6.4 million hectares of which can be powered by Solar PV. The region with largest recommended investment potential for solar-powered groundwater irrigation is western Africa (3.3 million hectares) followed by southern Africa (1.4 million hectares), eastern Africa (1.2 million hectares) and central Africa (0.5 million hectares).
- The joint irrigation-energy planning analysis shows that solar PV can serve as a cost-effective option to support groundwater irrigation development in Sub-Saharan Africa. The proposed planning approach can also be applied at national level to provide more granular insights for joint irrigation and energy investment.

Acknowledgement

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