

The Potential of Solar-Powered Irrigation in Reducing Greenhouse Gas Emissions from Irrigation Water Pumping in Kenya

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Introduction

Agriculture is a key sector of Kenya's economy, contributing about [20 percent of gross domestic product \(GDP\) and employing more than 70 percent](#) of the rural population. Despite significant progress over the past few decades, the agriculture sector faces enormous challenges in intensifying production to meet increasing demand driven by economic growth and population expansion.

Crop production in Kenya is currently predominantly rainfed, [with only about 1 percent of cropland equipped for irrigation](#). This leaves agricultural production highly vulnerable to worsening climate risks and limits farming opportunities during the dry season. Expanding irrigation is considered a promising strategy for increasing agricultural productivity and rural incomes as well as increasing climate resilience in Kenya. To this end, in 2025, the government launched the National Irrigation Sector Investment Plan (NISIP), which aims to enable irrigation-led growth in the agriculture sector and is supported by an ambitious investment plan. However, while irrigation can improve crop yields and production stability, irrigation development may also have far-reaching environmental impacts.

A significant concern is the energy intensity of mechanized irrigation systems used for lifting irrigation water. Recent advances in solar irrigation technologies have emerged as a potential game changer in addressing this challenge. Solar irrigation systems reduce dependence on fossil fuels and, therefore, offer opportunities to reduce the greenhouse gas (GHG) emissions associated with the expansion of irrigated agriculture.

However, the scale of climate mitigation achieved by replacing fossil fuel-powered with solar-powered irrigation systems depends on several factors, including the relative cost-efficiency of solar versus diesel systems and the potential for expansion of irrigated agriculture. Any expansion, in turn, depends on the availability of water resources and the market demand for irrigated crops.

This policy note presents the main findings from an IFPRI forecasting analysis that quantifies the potential for reducing GHG emissions through the adoption of solar-powered irrigation systems in Kenya. The study focuses specifically on groundwater irrigation systems, where energy consumption for water pumping is typically concentrated.

Against a backdrop of growing interest among national government agencies, international development partners, and private sector actors in promoting solar irrigation across Africa, including Kenya, this analysis aims to inform more effective policy and investment to support the role of solar irrigation in advancing climate-smart agricultural development.

Opportunities to reduce GHG emissions through solar-powered irrigation

Data assembly and simulation modeling

For this analysis, a geographic domain with highly favourable conditions for groundwater irrigation development is first delineated using multiple criteria, including terrain, aquifer properties, market accessibility, existing land use, and other relevant biophysical and socioeconomic factors. Irrigation water demand and the energy required for groundwater pumping within this domain are then estimated based on crop characteristics and environmental variables such as temperature, rainfall, and groundwater table depth. The resulting energy requirements are subsequently used to determine diesel irrigation system capacity requirements, diesel fuel consumption, and the associated GHG emissions.

Figure 1 presents the estimated annual GHG emissions associated with the irrigated cultivation of selected crops using diesel-powered, groundwater-fed irrigation systems across the groundwater irrigation suitability domain. Emissions vary considerably among crop types and exhibit substantial spatial variability. Estimated emissions range from a few hundred kilograms of carbon dioxide equivalent (CO₂-e) per hectare per year for crops with relatively low water requirements grown in areas with shallow groundwater tables and higher rainfall, to several thousand kilograms of CO₂-e per hectare per year in locations characterized by deeper groundwater levels, lower rainfall, and the cultivation of more water-intensive crops. These results provide a baseline against which the environmental performance of solar-powered irrigation systems can be evaluated, particularly with respect to their potential for reducing GHG emissions.

Following the sizing analysis of diesel irrigation systems, the required solar photovoltaic (PV) capacity for solar-powered irrigation systems is determined using a similar approach, while also accounting for additional factors related to the spatial distribution of solar radiation. Based on the system sizing results, the costs of solar- and diesel-powered water pumping systems—including both capital expenditures and operating costs over the lifespan of the irrigation system investment—are compared.

In the second stage of the analysis, the adoption of both solar- and diesel-powered irrigation systems is simulated under combined constraints related to water availability and market demand for irrigated crops. Farmers are assumed to select the most profitable crops and the irrigation technology option (solar or diesel) that minimizes irrigation-related production costs.

Results

The model generates probabilistic forecasts of groundwater-fed irrigation adoption, as shown in Figure 2(a). Figure 2(b) presents areas with differing probabilities of adopting solar-powered groundwater-fed irrigation. Results consider projected irrigation adoption and technology choice probabilities and the underlying irrigated crop mix. Excess production of high-value irrigated crops is avoided by simulating associated declines of prices when production surpasses demand.

Table 1 summarizes results at the county level, including estimates of the potential area adopting solar-powered irrigation, total groundwater-fed irrigation development potential, and the associated reductions in GHG emissions resulting from the substitution of diesel-powered with solar-powered irrigation technology.

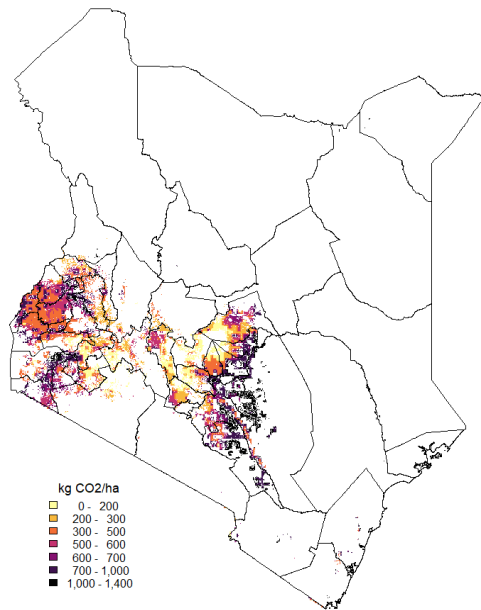
The total groundwater-fed irrigation potential in Kenya is estimated at 855,000 ha, with the largest production potential for vegetables, beans, and maize. Of this total, approximately 452,000 ha are estimated to adopt solar-powered irrigation. Figure 2(b) suggests substantial spatial heterogeneity, with solar-powered irrigation dominating in the westernmost and easternmost parts of suitable aquifer systems. This pattern reflects the complex interactions among environmental factors that influence the relative profitability of solar-powered and diesel-powered irrigation technologies.

Table 1. Groundwater-fed irrigation development potential and GHG emissions reduction potential from solar-powered irrigation system adoption in Kenya

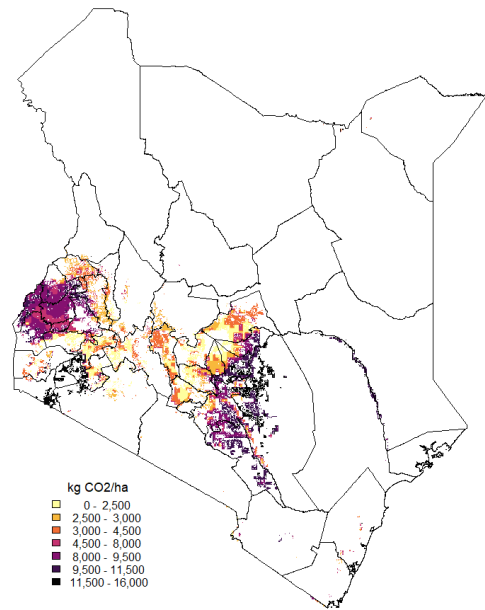
County	Potential solar-powered irrigated area (ha)	Total irrigation potential (ha)	GHG emissions reduction potential (tons CO ₂ e/year)	GHG emissions reduction (%)
Nakuru	38,744	55,255	13,924	79.2%
Kisumu	34,237	36,447	14,491	93.0%
Siaya	28,139	30,141	16,563	94.2%
Uasin Gishu	25,059	50,387	12,398	56.9%
Busia	24,203	24,475	15,069	98.9%
Kitui	23,196	23,289	30,840	99.7%
Kakamega	22,332	43,901	13,993	55.7%
Homa Bay	20,727	38,481	15,041	56.3%
Machakos	19,379	19,379	14,985	100.0%
Bungoma	18,914	37,532	12,565	57.7%
Trans-Nzoia	17,690	27,347	7,736	70.4%
Nandi	17,119	33,384	11,537	55.1%
Makueni	16,901	17,199	16,548	99.2%
Kericho	14,664	42,013	4,374	30.8%
Nyandarua	14,549	32,121	6,414	65.0%
Meru	12,786	24,304	6,838	70.0%
Murang'a	12,774	15,368	4,234	93.0%
Baringo	10,703	18,344	4,306	62.6%
All other counties	80,530	285,710	58,234	37.7%
Total	452,646	855,077	280,090	61.5%

Source: Authors.

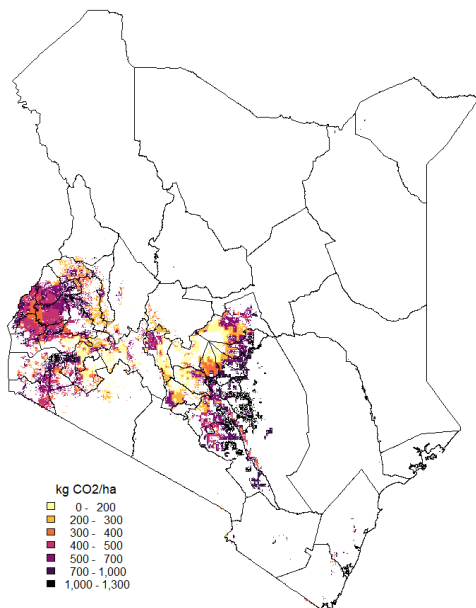
(a) Maize



(b) Rice



(c) Vegetables



(d) Beans

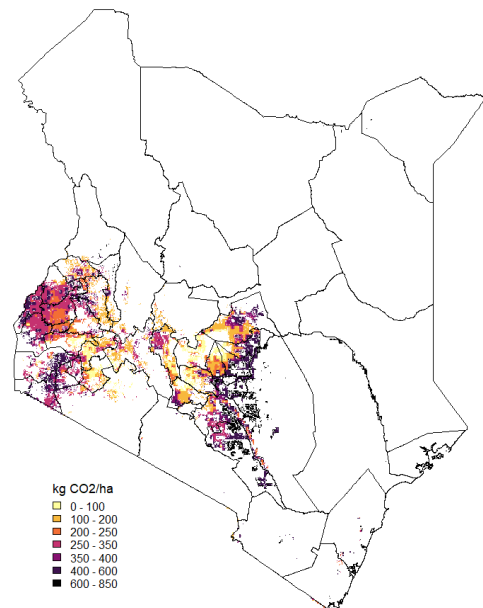


Figure 1. Estimated annual GHG emissions from diesel-powered groundwater pumping for irrigation

Source: Authors.

The calculated adoption values correspond to an annual emissions reduction of approximately 280,000 tons CO₂-e, representing a 61.5 percent reduction in GHG emissions from diesel-fuel combustion for groundwater pumping compared with a scenario in which all groundwater irrigation development relies on diesel-powered pumping.

Counties with the greatest potential for solar irrigation adoption and reductions in GHG emissions include Kitui, Siaya, Makueni, and Busia. These findings highlight the important role

that solar irrigation can play in expanding irrigated agricultural production in Kenya while reducing the carbon footprint associated with groundwater pumping.

(a) Probability of adoption

(b) Irrigation technology

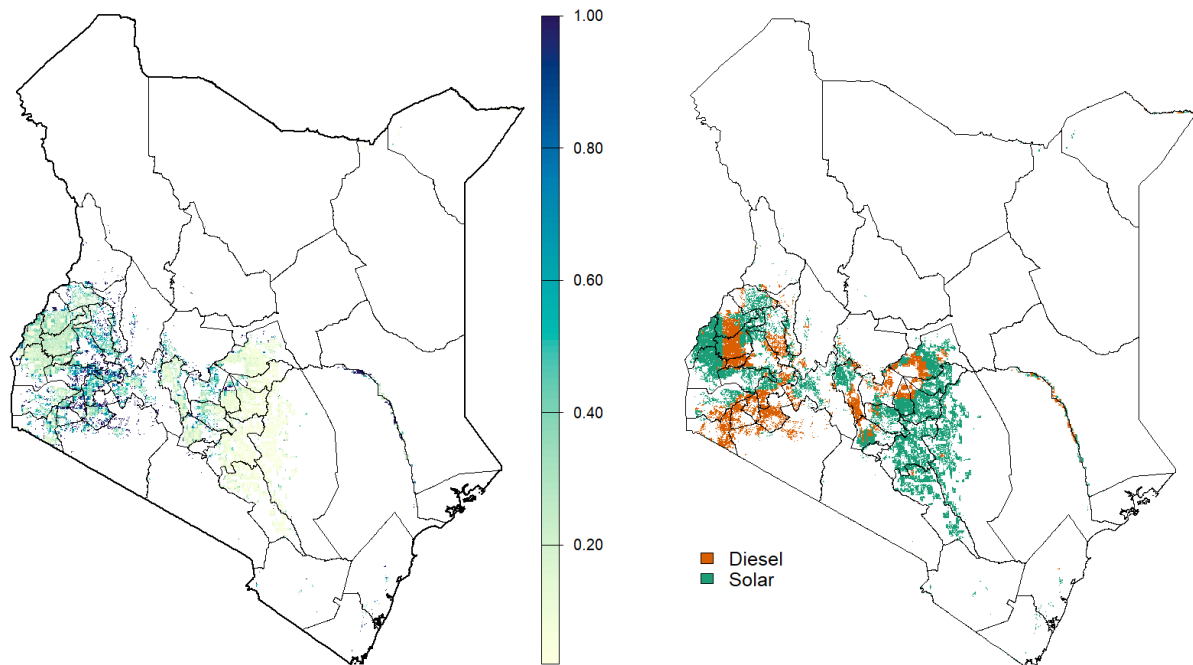


Figure 2. Projected probability of adoption of groundwater-fed irrigation and irrigation technology selection

Source: Authors.

The way forward

Kenya's NISIP includes five pathways to productive irrigation. Among these, farmer-led irrigation is growing particularly rapidly. On this pathway, farmers, alone or in small groups, purchase their own irrigation technology, such as a diesel or solar irrigation pump; develop their own water source, for example, a borehole; and are otherwise independent entrepreneurs. An alternative option is for farmers to [receive irrigation services](#) from companies that provide irrigation on demand, so the farmers do not need to purchase the equipment.

Kenya has a vibrant market for irrigation technologies. An example is SunCulture, which provides a range of business and finance models, including end-to-end services to farmer irrigators. A particularly innovative element is SunCulture's access to the carbon market through GHG-emissions-avoidance credits, verified by Verra. This has allowed the company to reduce the cost of solar pumps by up to US\$170 per pump, [or by up to 17-25 percent per pump](#), but prices vary with the carbon market. Such measures, if scaled up by SunCulture and other providers, could further increase the calculated share of solar-powered hectareage in total expansion of irrigated area. Reaching Kenya's full groundwater-fed irrigation potential will require increased availability of a range of locally appropriate financial products, given the much larger financial outlay and therefore longer payback periods for water pumps compared

to other farmer expenses, such as fertilizer costs, for which credit can typically be paid back at the end of a growing season. Asset-based financing, such as already offered by private sector operators, should also be offered by commercial banks and providers of microfinance products to support these investments.

Government agencies, such as the Ministry of Water Resources and Sanitation and the National Irrigation Authority, also have important roles to play, particularly in identifying suitable, sustainable groundwater aquifers and in upholding local land rights systems that are essential for farmers to invest in costly water infrastructure.

Capacity sharing focused on managing irrigated ecosystems, including efficient irrigation application, agronomic practices in irrigated environments, and suitable crop pest management in the dry season, as well as marketing of irrigated produce, are some of the many measures that need to also be rolled out for the promise of sustainable and equitable farmer-led irrigation to become reality.

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