Solar Water Pump Market Sizing Methods

Figure 1 – Farm Plot in the Nakuru region of Kenya

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Introduction:

Irrigation of arable land has the potential to boost crop yield and enable cultivation of the same plot more than once a year. Irrigation provides farmers with a way to grow high value crops and strategically align harvest schedules with periods of favorable market prices. In rural settings without access to an electrical grid, irrigation has typically been implemented with a coupled pump and diesel engine. Leveraging recent reductions in the price of photovoltaic (PV) technology, coupled pump and PV components (solar water pumps) have gained market traction and are now a technically viable and more sustainable alternative to diesel powered systems.

However, barriers to solar pump market success remain, particularly where adoption of diesel irrigation is low. A few examples include accurate customer identification and technology matching, lending models, and capacity building.

Objectives:

The objective of these methods is to provide both visual and quantitative representations of the potential for solar pump sales – addressing the accurate customer identification market barrier.

The analysis methods are limited to assessing the potential of a solar pump sale based on the benefit provided to a farmer and does not include the factors that may influence a farmer's capacity to successfully adopt a solar pump, nor the cost of delivering that product.

Methods

Software Tools

ArcMap, a geographical information system (GIS) platform, and Microsoft excel are the software tools proposed. ArcMap can be leveraged to conduct overlay analyses and selection algorithms for the selection and compilation of various data layers of interest. Microsoft excel can be leveraged to graph data over time and provide decision making criteria for the overlay analyses.

Excel Analysis

Before selecting and compiling data layers in ArcMap, excel can be used to conduct a crop financial analysis. The objective of this analysis is to understand which crops, if harvested in an off-cycle period with the aid of a solar pump, could result in the highest profits. The crops included in the analysis and subsequent crop type layer is determined by geography. The below example is from Western Kenya (Table 1).

Table 1 – Common Crop Types in Western Kenya

<table>
<tr><th colspan="2">Crop Type</th></tr>
<tr><td>Beans</td><td>Tomatoes</td></tr>
<tr><td>Onions</td><td>Wheat</td></tr>
<tr><td>Potatoes</td><td rowspan="2">Maize</td></tr>
<tr><td>Sorghum</td></tr>
</table>

For those crop types, publicly available datasets with monthly market price information ($/kg) can be used and graphed over average monthly precipitation amount [1], [2]. Additionally, country data for harvested area (ha) and total production (tonnes) for each crop type can be incorporated for the calculation of crop yield (tonnes/hectare) [3].

Total Crop Production (tonnes) ÷ Total Crop Harvested Area (ha) = Crop Yield (t/ha)

Using the minimum and maximum market price for each crop and assuming the minimum price coincides with typical harvest periods (when supply is meaningfully higher), the upside potential for off-cycle harvesting using an irrigation system can be calculated for a quarter hectare. Upside potential is defined here as the marginal increase in revenue a farmer could receive by selling a crop at its highest market price throughout the year. Sourcing planting times and days to maturity for each crop to identify the typical planting and harvesting cycles is best practice to determine upside potential for off-cycle harvesting. Often this data is not available and assumptions are necessary.

[Maximum Crop Price ($/kg) – Minimum Crop Price ($/kg)] x Crop Yield (t/ha) x 1000 kg/t x 0.25
= $/ quarter-ha

This analysis may produce a ranked list of crops based on upside potential, enabling identification of crop types that are more likely to benefit from irrigation. The ranked list can provide an effective filtering layer for customer identification in the geospatial analysis, which follows. Potential data to be included in an analysis is in Table 2 below.

Table 2 - Potential excel analysis data information

Data	Provider	Source
Precipitation	United Nations	http://data.un.org/Data.aspx?d=CLINO&f=ElementCode%3A06
Crop Production	FAOSTAT	http://www.fao.org/faostat/en/#data/QC. [Accessed: 22-May-2018]
Crop Prices (Kenya)	NAFIS	http://www.nafis.go.ke/category/market-info/

Figure 2 and Table 3 provide one example of the outputs of a crop excel analysis.

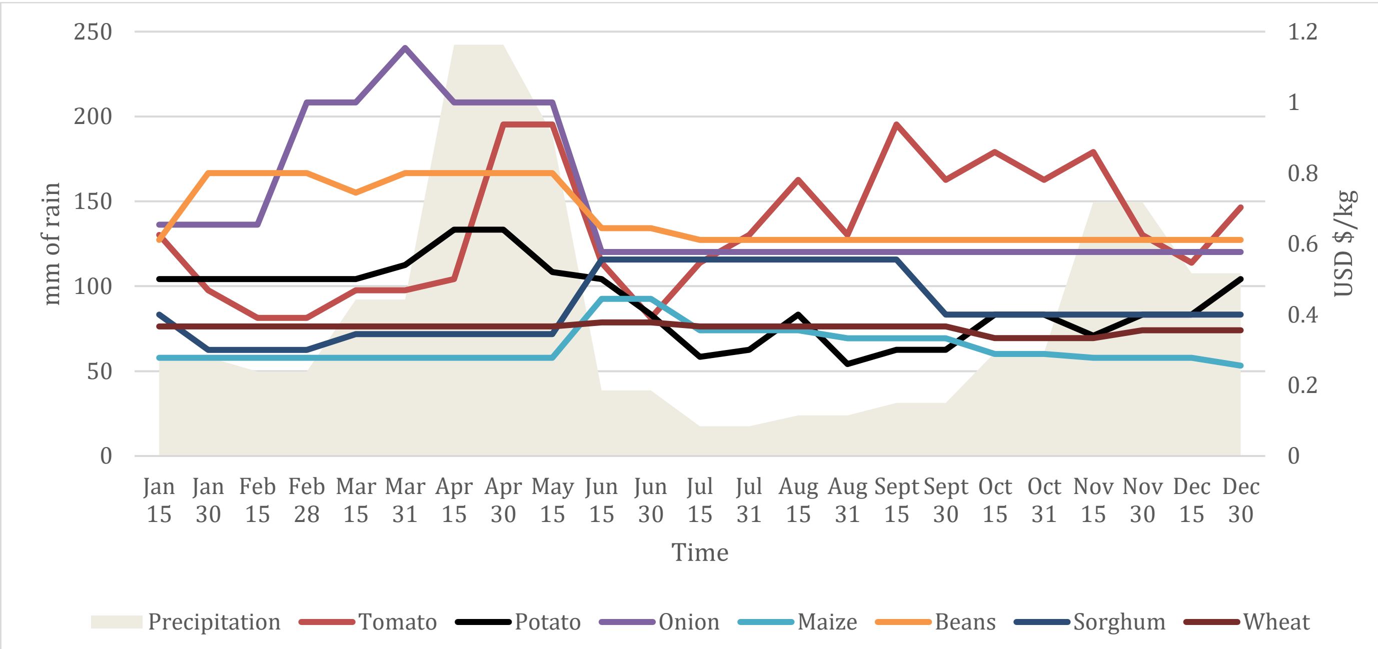

Figure 2 – Crop Price Information Against Precipitation Example

Table 3 – Results of a Crop Financial Analysis Example

Crop Type	Harvested Area (ha)	Total Production (t)	Yield (t/ha)	$/kg min	$/kg max	upside $/quarter ha/year
Tomato	21,921	410,033	18.7	0.391	0.938	2,557.33
Onions	8,579	122,841	14.3	0.577	1.154	2,065.21
Potatoes	145,967	1,335,883	9.2	0.260	0.640	869.44
Maize	2,337,586	3,339,000	1.4	0.256	0.444	67.45
Sorghum	184,654	117,000	0.6	0.300	0.556	40.48
Beans	1,171,710	728,160	0.6	0.611	0.800	29.35
Wheat	153,119	222,400	1.5	0.333	0.378	16.14

To enhance the sophistication of this analysis, monthly irrigation requirement calculations for each crop could be included in a scenario using crop coefficients, evapotranspiration rates defined by local climate, soil type and soil moisture retention rates, and effective rainfall. Such calculations may indicate the level of impact a solar pump can provide for respective crop varieties outside of the long rains harvest cycle. Required irrigation calculations may also result in the conclusion that certain crops require more water than is feasibly provided by an affordable solar water pump.

Data Layers

Where particular datasets are available, customer data can be combined with environmental resources data to hone in on potential solar water pump customers (Figure 3). The water line connection and irrigation equipment layer is included to exclude farmers who have access to a pressurized source of water, negating any need for a pump, or who already have a diesel pump and could be converted to a solar pump. Economic/energy status is included to gauge a customer's ability to repay a solar pump loan. Credit score is the preferred indicator, but where not available, we hypothesize that ownership of energy assets like modern solar home systems could serve as a good proxy. Crop type is included to size the market of farmers who are already cultivating crops that benefit most from irrigation, such as horticultural crops. The relevant crop types will vary by market and per the results of the excel analysis.

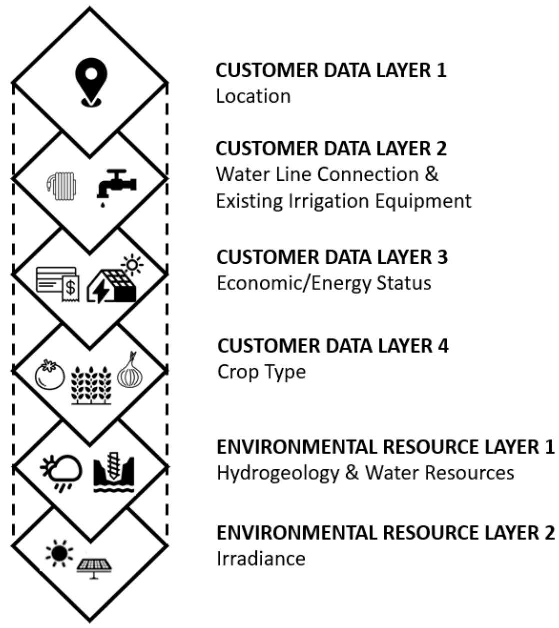

Figure 3 – Data Layers

Regarding environmental resources layers, hydrogeology, water resources, soil type, and irradiance data can contribute to determining solar water pump suitability for a customer. Hydrogeology data such as sub-surface characteristics can infer areas that are prone to have shallower water tables and greater ability to store water. Hydrogeology data such as depth to groundwater can be included to exclude farmers with groundwater deeper than 25 meters that would require a larger submersible pump [4]. Larger submersible pumps have a higher capital cost, are less common in the market, and have a payback period that may exceed a reasonable horizon. Water resources data such as proximity to surface water can provide an indication of a farmer's ability to pull from an alternative water source, given the water table is too deep. Lastly, irradiation data can gauge the ability of a pump to run on solar power. Potential environmental data layers to be included in an analysis is in Table 4 below. Specific customer datasets may be sourced through organizations and companies active on the ground.

Table 4 - Potential environmental data layer information

Layer	Provider	Source
Sub-Surface Characteristics - TBD	British Geological Survey	In development
Depth to Groundwater – 2012	British Geological Survey	http://www.bgs.ac.uk/research/groundwater/international/africangroundwater/mapsDownload.html
Surface Waters - 2017	ICPAC GeoPortal	http://geoportal.icpac.net/layers/geonode%3Aken_water_lines_dcw
GTI Irradiance - 2017	Global Solar Atlas	http://globalsolaratlas.info/downloads/kenya

Geospatial Analysis

Geospatial analyses are nimble and can be adjusted based on available data and desired outputs. The below method is based on a specific scenario and includes a select few of the comprehensive data layers listed above.

Of the crops in the excel analysis example, tomatoes, onions, and potatoes rose to the top with the highest upside potential, guiding the data layer selection method in ArcMap. Figure 4 outlines one example of an ArcMap filtering procedure and defines four categories into which customer data could be separated:

1. Farmers already connected to a pressurized water line or without reasonable access to groundwater
2. Farmers with reasonable access to groundwater, growing tomatoes, onions, or potatoes, but rated with a poor credit score
3. Farmers with reasonable access to groundwater, growing tomatoes, onions, or potatoes and rated with an acceptable credit score
4. Farmers with reasonable access to groundwater, growing any crop and rated with an acceptable credit score

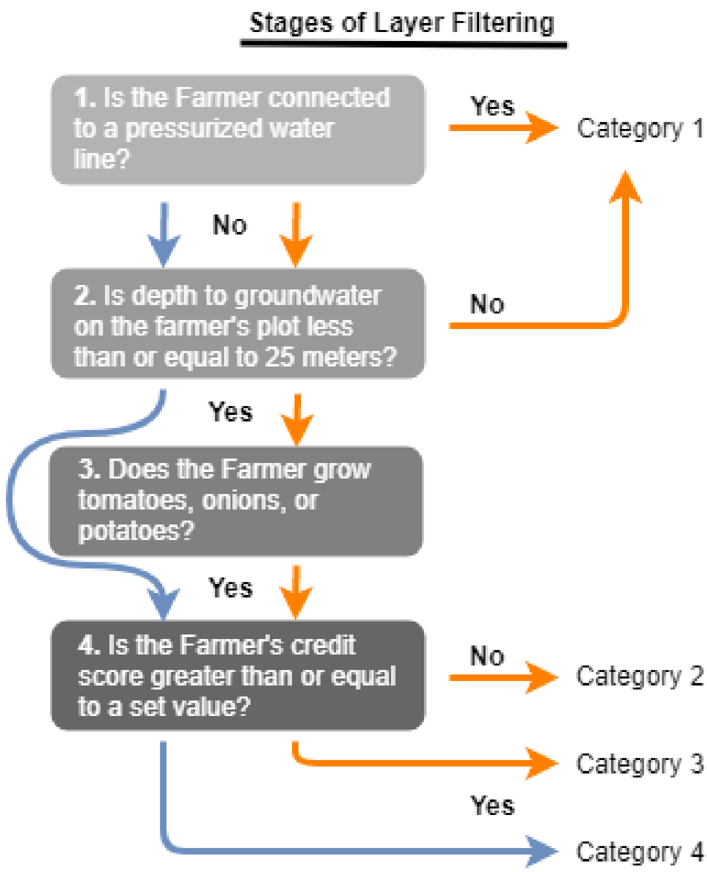

Figure 4 – ArcMap Layer Filtering Method

To geospatially categorize the customer data in the above example, xy location data was uploaded to ArcMap and converted into a geodatabase. Using the 'Extract Values to Points' tool, the depth to groundwater raster values were appended to the customer data's attribute table. This step associates each customer point with one of the four depth to groundwater ranges: 0-7, 7-25, 25-50, and 50-100 meters. The updated customer survey geodatabase was filtered for each of the criteria in Figure 4 using SQL commands in the 'Select by Attributes' tool and exported to a new geodatabase for each category.

Technology Matching

Customers that are identified using the above methods can be, at a high level, matched with a solar pump off the market (examples in Table 5 below). Farmers within close proximity to surface water and access to shallow wells could be paired with a surface pump, while other farmers may be paired with a submersible pump. If the plot size for each crop type is gathered for each of these farmers and compared to required irrigation calculations, then the appropriate size and model of pump can be determined.

Table 5 – Example List of Solar Pump Manufacturers

Make	Model	Category	Type
Amped Innovation	Prototype	Surface	Rotodynamic
Dankoff	Various	Surface	Reciprocating
Dingfeng	Various	Submersible	Rotodynamic
Encap Technologies	Prototype	Submersible	Rotodynamic
Ennos	Sunlight	Surface	Progressive Cavity
FuturePump	Sunflower	Surface	Reciprocating
Grundfos	Various	Surface/Submersible	Various
Khethworks	Prototype	Submersible	Rotodynamic
Lorentz	Various	Surface/Submersible	Various
Nemo Solar/Flojet	Various	Surface/Submersible	Various
Ningbo	Various	Surface/Submersible	Various
SHURflo	Various	Surface/Submersible	Reciprocating
Solartech	Various	Submersible	Progressive Cavity
SunPumps	Various	Surface/Submersible	Various
Taifu	Various	Surface/Submersible	Various
Xinya	Various	Surface/Submersible	Various
Zhejuang Feili	Various	Submersible	Progressive Cavity

Concluding Note

In general, the opportunity to build upon numerical and geospatial analyses for solar pump potential becomes more and more exciting as greater amounts of farmer and farmgate specific data and environmental data become available.

References:

[1] "Agricultural Commodities Market Information – NAFIS." [Online]. Available: http://www.nafis.go.ke/category/market-info/. [Accessed: 22-May-2018].
[2] "UNdata | record view | Precipitation." [Online]. Available: http://data.un.org/Data.aspx?d=CLINO&f=ElementCode%3A06. [Accessed: 22-May-2018].
[3] "FAOSTAT." [Online]. Available: http://www.fao.org/faostat/en/#data/QC. [Accessed: 22-May-2018].
[4] M. Otoo, N. Lefore, P. Schmitter, J. Barron, and G. Gebregziabher, "Business model scenarios and suitability: Smallholder solar pump-based irrigation in Ethiopia," p. 71.