Accelerating Solar Water Pump Sales in Kenya: Return on Investment Case Studies

Jennifer Holthaus[1], Bikash Pandey[1], Robert Foster[1], Bernard Ngetich[2], James Mbwika[3], Evgenia Sokolova,[4] and Philip Siminyu[5]

[1] Winrock International, Arlington, Virginia (United States)

[2] Winrock International, Nairobi (Kenya)

[3]Value Chain Consultant, Nairobi (Kenya)

[4]Enterprise Finance Consultant, Madrid (Spain)

[5]Agricultural Economics Consultant, Nairobi (Kenya)

Abstract

Irrigation allows smallholder farmers to increase their yields and to grow two or even three crops of high-value vegetables and fruits a year, receiving higher commodity prices during the off-season. In Kenya in 2010, 2.5 million smallholders generated 80% of national horticulture production. Inexpensive diesel water pumps (US $200) are available, but fuel purchase and transport costs are significant (typically US $100–$300 per 3-month season for one acre); as a result farmers are conservative with, or cannot afford, diesel irrigation. Return on Investment case studies by Winrock International show an increase in gross profits of up to 186% within one to two crop seasons after purchase of a solar water pump (SWP). Between August 2015 and December 2016 Winrock demonstrated SWPs to more than 16,000 smallholder farmers in Kenya and found that despite strong demand, the lack of smallholder credit options for solar irrigation is a key obstacle preventing SWP sales from increasing rapidly; financial institutions and SWP retailers need technical assistance to facilitate smallholder access to credit.

Keywords: smallholder, solar irrigation, solar water pump, finance, return on investment, Kenya

1. Introduction

In Kenya in 2010, 2.5 million smallholders generated 80% of horticulture production. 80% of the country's land surface is classified as arid and semi-arid; the majority of people living in rural areas depend on rain-fed agriculture for their livelihoods. Historically, rains occurred in January, February, November and December, with dry conditions the rest of the year. Climate change is affecting rainfall patterns, which in turn is causing increased crop failures and lower yields. Expanding irrigation is a key mitigation strategy for smallholders (Karina 2011). Irrigation can assist in agricultural diversification, enhance food self-sufficiency, increase rural incomes, generate foreign exchange and provide employment opportunities when water is a constraint (Ngigi 2002). Irrigation can allow smallholder farmers to increase their yields and grow two or even three crops of high-value vegetables and fruits a year, receiving higher commodity prices in the dry seasons.

Winrock International is a non-profit organization that works to empower the disadvantaged, increase economic opportunity and sustain natural resources around the world. Winrock has been working to increase smallholder productivity and income through affordable on-farm solar technologies, including solar chillers and solar water pumps.

Solar water pumping is a mature, reliable, and economically attractive solution for off-grid irrigation, livestock water, and community water supply. A 2008 Rutgers University study showed that vegetable growing using solar irrigation is cost effective compared to grid-connected drip irrigation. Given that rural smallholders in Kenya have an increasing need for irrigation but limited access to conventional energy sources, solar water pumps (SWPs) are a critical tool for ensuring food security and decreasing poverty. However, smallholder adoption of solar irrigation is hampered by lack of awareness of affordable, high-quality solar pump products, and lack of access to finance for solar pump purchases.

2. Solar Water Pumps in Kenya: Supply and Demand

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In mid-2015, when Winrock International began demonstrating solar water pumps (SWPs) in Kenya under the USAID-funded Kenya Smallholder Solar Irrigation (KSSI) project, there were two high-quality, affordable small scale SWPs locally available. The US $450 SunFlower pump by Futurepump was designed to operate up to 10 meters Total Dynamic Head (TDH), and the US $2,200 SunCulture SP-300 pump was designed to operate up to 50 meters TDH (Kunen, 2015). SWP retailers were receiving individual pump orders but having difficulty aggregating purchases from smallholder farmers (<2 acres). During farmer field days attended by more than 16,000 farmers between August 2015 and December 2016, Winrock found very high interest in SWPs among farmers, but few had the cash needed to purchase a SWP. The most frequent comments from farmers were that the SWPs should be cheaper, and that financing would greatly facilitate purchases.

By early 2017 there were four high-quality affordable small scale SWPs locally available, including the new $350 Majipump MP 400 offered by Chloride Exide, and the $1,500 D3Solar offered by Davis & Shirtliff. The SunFlower had increased in price to US $650 and the SunCulture SP-300 pump had decreased to US $1,740. In October 2017 SunCulture launched the US $500 RainMaker pump, which claims to pump 7,000 liters per day at 100 meters total dynamic head, but has not yet been tested by Winrock. Given that the majority of the 5 million smallholder farmers in Kenya live in areas where TDH is between 10 and 50 meters (**Fig. 1**), Winrock estimates conservatively that 2 million smallholders in Kenya could achieve significant income benefits from the SWPs currently on the market. An efficient way to accelerate commercial sales of SWPs is through existing aggregation mechanisms targeting smallholder horticulture producers, including cooperatives, wholesale buyers, exporters, and processors.

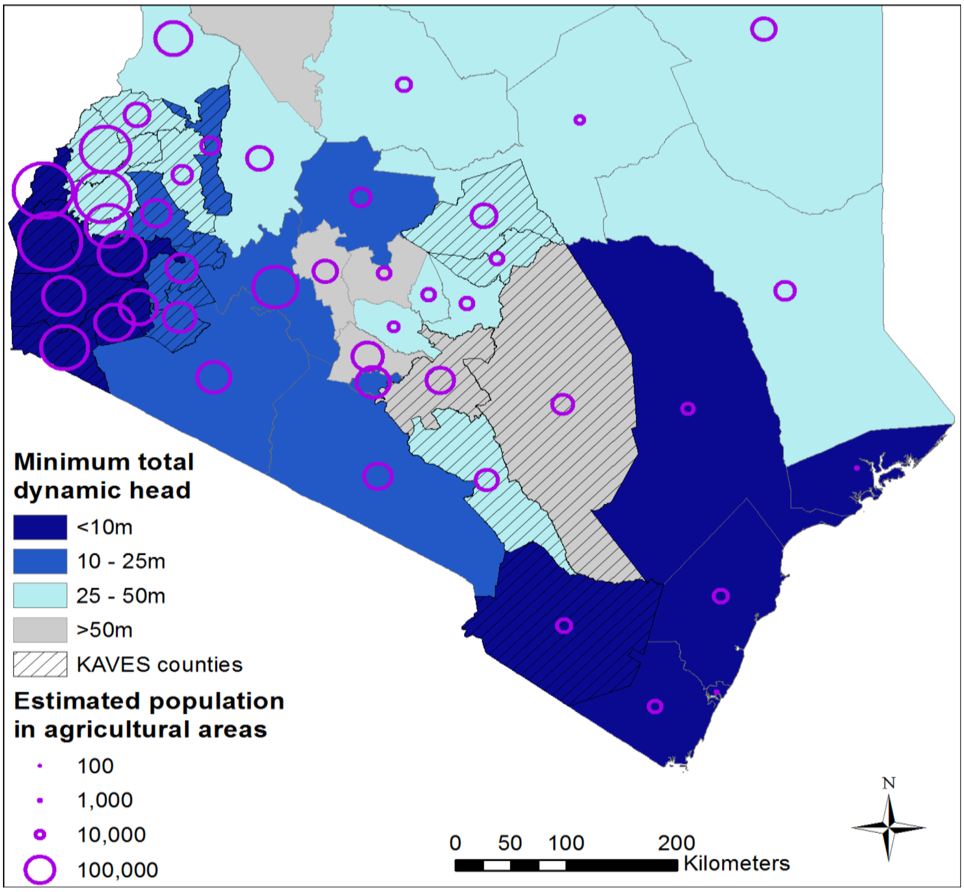

Fig. 1: Minimum total dynamic head vs estimated farmer population in Kenyan counties.

3. Smallholder Finance Options

Between August 2015 and May 2016, KSSI facilitated demonstrations of the Futurepump SWP at farmer field days hosted by the Kenya Agricultural Value Chain Enterprises project. More than 8,000 farmers visited the Futurepump booth, yet only 9 SWPs were sold for cash during the events. In late 2015 Winrock began an effort to facilitate solar pump finance from Kenyan financial institutions (FIs). At the time Winrock could only identify one FI, Equity Bank Kenya, with an existing solar pump loan product for smallholders. Equity reported that, because of perceived high credit risk, they had rejected most of the 200 solar pump loan applications they had received since they created the loan product. Reasons included lack of farming experience or an alternative salaried income; lack of land ownership; and lack of required collateral.

Interviews with more than 20 Kenyan FIs showed that prevailing loan terms – if solar pumps were classified as agricultural loans – would be difficult for most smallholders to meet. Annual interest rates were 22% and up; a 20-30% down payment was required; and some FIs also required credit and crop insurance, which each added up to 10% in one-off interest fees. However, every FI interviewed by Winrock expressed interest in solar pumps as a way to mitigate risks of rainfall variability and drought, therefore lowering overall default rates in their existing agricultural portfolios. FIs acknowledged the high demand for solar pumps from their clients, but were hesitant to enter the market because of uncertainties about supply, performance, and cost of solar pump products.

Winrock selected five FIs as potential partners to create solar pump loan products. All five FIs had offices in areas with high solar pump demand and strong distribution and after-sales support from retailers. Three FIs – Juhudi Kilimo, ECLOF Kenya (through its affiliate Ecosmart Energy Limited, a renewable energy distributer), and the Kenya Union of Savings and Credit Co-operatives (KUSCCO) – moved forward with Winrock-supported loan pilots under the following terms:

- Commitment to lend to at least 50 SWPs over a period of 3 months;
- Affordability of credit to smallholder farmers, defined as owning less than 5 acres and having limited financial history and physical collateral;
- Availability of capital to put toward SWP loans;
- Willingness to share training costs;
- Strong senior management buy-in; and
- Readiness of systems and internal processes to lend into a new product.

Winrock served as a bridge between two FIs and a solar pump retailer, assisting them to negotiate terms for pricing, target sales volumes, demonstration pump units, distribution and after-sales support. FIs were reluctant to handle stock (which also results in a Value-Added Tax that they are not able to charge to loan clients), so an intermediary distributor or stockist was engaged near FI branch offices.

To decrease the risk perception of the FIs, Winrock provided data on farm-level return on investment case studies (**Section 5**), which showed payback times of 1.5 years or less; and on typical solar pump warranties (20 years for solar panels, 2 years for pumps). The warranty and payback periods match well with a 2-year loan tenor. Winrock advised the FIs to classify solar pump loans as asset financing, typically viewed as less risky, requiring less collateral and enabling better loan pricing. Winrock also provided solar pump technical training to FI senior management teams and branch loan officers.

During an initial loan marketing phase, issues that required troubleshooting from Winrock included miscommunication over pump delivery logistics, and adjustments to the marketing strategy to ensure that loan officers were targeting savings groups that had the capacity to take on new loans.

After 6 months, results included 5 solar pump loans made by Juhudi Kilimo, and 40 smallholders who had initiated savings with Ecosmart to qualify for a solar pump loan. One year later, the emergence of two lower-cost SWPs on the market has caused Juhudi Kilimo to adjust its SWP product offering, since many of its clients need a higher-powered pump than the one they had been offering. They plan to incresae the SWP loan size to include a water tank, piping and drip irrigation kit. Given the 2017 drought in Kenya they are also assessing other solutions including water conveyance and storage. Ecosmart is also seeking to offer one of the new lower-cost SWPs, as many of their clients felt the price of the original SWP product was too high. ECLOF's members have saved US $3,000 toward SWP loans.

Key lessons learned were:

- Co-guarantees in a group lending arrangement did alleviate prohibitive collateral requirements, but required a lead time of at least 3 months or more for existing loan groups to build up the required savings for credit disbursal. For new farmer groups the lead time was nearly double that of existing loan groups.

- Solar pump products must match smallholder needs in several key ways: the pump must perform at the required TDH; accessories must also be offered on credit if needed by farmers (e.g. pipes, water tank and/or irrigation drip kit); and smallholders must perceive that the SWP price is affordable.
- Aggregation mechanisms are an effective next step to gain scale and reduce costs when commercializing a new technology. Aggregation brings about volumes and bulk pricing discounts that eventually lead to lower prices for smallholders. For technical assistance providers, aggregation also offers economies of scale to reach thousands of farmers while minimizing program costs.

4. Pump Technologies Deployed

The KSSI project installed several types of solar water pumps for crop irrigation and aquaculture. There are two families of pump mechanisms with a range of options depending on water volume needs, pumping depth, and lift; thus there are two mechanical principles by which a pump can create pressure. Displacement pumps (also called positive displacement or volumetric pumps) move water by isolating it in sealed chambers, and applying mechanical action to force it upward. Displacement pumps work efficiently through wide ranges of speed and head. The KSSI project used mostly positive displacement pumps for small pumpig systems <2kW in both surface and submersible configurations as described in the following sections.

3.1 Reciprocating Displacement Pump

The SunFlower pump (**Fig. 2**), sold by Futurepump, is a portable solar irrigation pump manufactured in India. It raises a close-fitting piston in a submerged pipe to draw water up behind it to fill the vacuum which would otherwise occur; this works only up to a certain limit of the height water can be pulled by suction (~10 m maximum limit), see **Fig. 3**. The piston serves to create a vacuum and the water is actually displaced by atmospheric pressure pressing on its external surface. So water is displaced by "pulling." The KSSI project facilitated deployment of 172 SunFlower pumps, mostly in the Lake Victoria region of Kenya (**Section 5.2**).

Fig. 2: Futurepump SunFlower (SF1) is a micro-size piston pump for small-farm irrigation. To reduce cost and complexity, it uses a two-speed manual transmission instead of an electronic controller, and manual solar tracking. Photo: Winrock International Kenya.

4.2 D iaphragm Pumps

Diaphragm pumps displace water by means of a diaphragm made from a flexible synthetic material (elastomer). Normally there are three or four pumping chambers, each with a check valve for the intake, and another for the outlet. Diaphragm pumps supply low volume water needs at high efficiency and low cost. A diaphragm pump may be used for solar pumping where the initial cost must be minimal, the water volume requirement is very low, and the future cost of maintenance frequent replacement is acceptable. Diaphragms normally need to be replaced after a two or three years of continuous use, due to normal material fatigue and wear. Manufacturers of these pumps provide replacement kits, or the entire pump may be replaced at low cost. Pumps that provide low lifts (the lower half of their capacity) can last longer than those operating at higher lifts. Diaphragm pumps are generally not a good choice for communal water pumping systems due to their higher maintenance requirements.

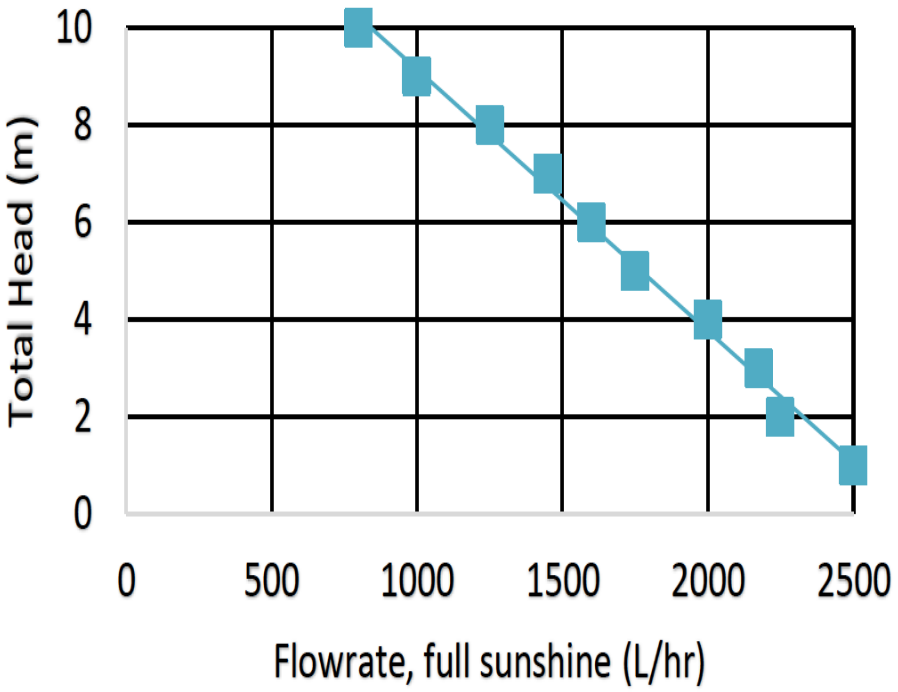

Fig. 3: As shown by the SunFlower pump manufacturer's performance curve, it can lift 2,000 lph at 4 m head at 1,000 W/m^2 irradiance using only an 80 Watt PV module. Courtesy: Futurepump

Diaphragm pumps are most appropriate for small volume requirements such as single-family drinking water or livestock pumping. If the pump is to be run every day, year-round, a HR pump should prove more economical in the long run.

Fig. 4: Winrock technicians inspecting two Ubink PV modules made in Kenya for the Machakos solar diaphragm pump system. The farmer brings her PV modules in at night for security reasons.

4.3 Helical Rotor Pumps

A helical rotor pump (HR) is a positive displacement pump that offers a wide range of volume and lift capacities at high efficiency. The pump end has only one moving part lubricated by water that produces continuous flow, free of pulsation (unlike a diaphragm pump) and requires no preventive maintenance. The HR pump has the best characteristics of any type of displacement pump due to its simplicity and reliability. It is optimum for flow ratesup to ~60 lpm for vertical lifts that exceed 20 m.

The HR pump's rotor is a helix made of stainless steel which fits precisely into a rubber stator (stationary outside tube), see **Fig. 5**. The inside surface of the stator is formed of two intertwined helixes, with an ovoid cross-section. The surfaces of the rotor and stator intersect to form a series of sealed cavities (hollow spaces). As a cavity forms at the intake end, it draws water in. As the rotor turns, the cavity seals and progresses upward (also called a progressive cavity pump). The pumped water lubricates the rotor. As with any pump, a high concentration of abrasive particles will cause premature wear of the rotor and stator.

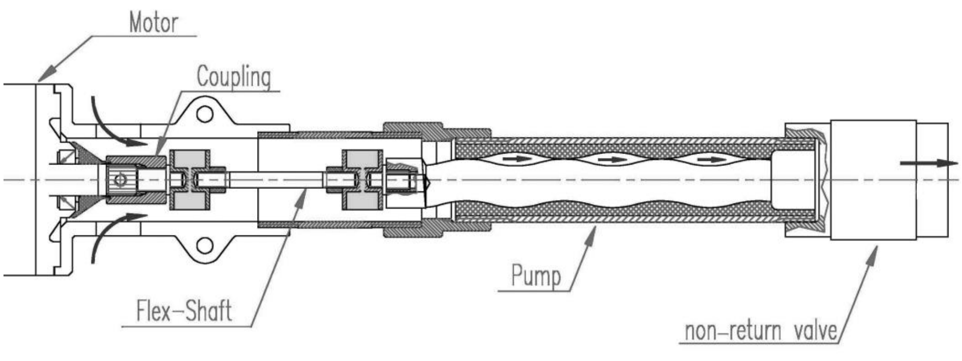

Fig. 5: Cross-section of typical helical rotor pump end (Foster et al, 2009).

A check valve at the pump's outlet prevents possible leakage downward when the pump is stopped. By relieving pressure, it tends to make the pump easier to start. The check valve closes only when the pump stops. Electronic controllers for HR pumps supply a boost of current, and precise control during startup. The KSSI project facilitated the installation of a relatively large solar pumping system in Nyandarua county, which uses an HR pump (**Fig. 6**).

Fig. 6: Lorentz helical rotor 8.1 kW_p solar water pumping system providing community and irrigation water supply to 500 farmers in Nyandarua County. The borehole is 230 meters.

5. Solar Pump Return on Investment Case Studies

Winrock conducted detailed farm-level return on investment case studies from 2015 to 2017. The case studies, which represent different pump price points, show strong returns within one to two crop seasons.

5.1 Solar drip irrigation in Machakos County

Mr. Shadrack Nzioka has farmed since 2006 in Muuani Village, Machakos County. He was using a diesel pump to transfer water to a pond, from which he irrigated 0.25 acre of onions with a treadle pump. In August 2015 Mr. Nzioka invested US $2,670 in a 27 meter borehole, a water tank, and land clearing. He purchased a US $2,500 SunCulture SWP and drip kit through a US $2,000 loan from Equity Bank at 18% interest; he will make a monthly loan payment of US $100 for two years. The helical rotor solar pump, which is powered by a 300 Wp solar module, automatically fills a water tank connected to drip irrigation (**Fig. 7**). During the first season after purchasing the SWP Mr. Nzioka irrigated 0.25 acres of onions. During the second season after purchasing the SWP Mr. Nzioka increased to a total of 0.875 acre: 0.25 acre of onions, 0.5 acre of passion fruit and 0.125 acre of tomatoes.

Fig. 7: Installation of water tank and drip lines at Shadrack Nzioka's farm.

The solar pump allowed Mr. Nzioka to increase his irrigated acreage from 0.25 to 0.875 acre, eliminate diesel fuel costs, and grow two crops per year instead of one. Using conservative estimates, he maintains his gross profit while paying off the two-year solar pump loan. Using conservative estimates, his gross profit is projected to increase by 100% after he pays off the loan. A profit and loss analysis for Mr. Nzioka is shown in **Table 1**.

Table 1: Shadrack Nzioka Profit and Loss Analysis

	Year 1 Actual		Year 2 Actual	Year 3 Projected
	Season 1 (Pre-SWP)	**Season 2 (Post-SWP)**	**Season 2**	**Season 2 (Post Loan)**
Farmer Profit and Loss Statement				
Acreage Planted	Onions 0.25	Onions 0.25	Onions 0.25; PF 0.50; Tomatoes 0.125	Onions 0.25; PF 0.50; Tomatoes 0.25
Total Yield (kg)	3,125	3,500	5,500	8,500
Yield change, %		*12%*	*57%*	*55%*
Total Revenues	**312,500**	**350,000**	**475,000**	**720,000**
Revenue growth, %		*12%*	*36%*	*52%*
Operating Costs	77,100	83,600	158,450	195,150
Diesel Pump Fuel and Transport	11,000	-	-	-
Pump maintenance	2,000	500	600	1,040
Total Operating Costs	**90,100**	**84,100**	**159,050**	**196,190**
Gross Profit	**222,400**	**265,900**	**315,950**	**523,810**
Gross Profit Margin, %	*71%*	*76%*	*67%*	*73%*
Loan + interest payment (6 months)	-	60,000	60,000	-
Earnings Before Taxes (EBIT)	**222,400**	**205,900**	**255,950**	**523,810**
Debt Coverage and Investment Returns				
SWP Total Upfront Investment	480,500		5 Yr Return on Investment (ROI)	3.61
financed by own savings	280,500		5 Yr Internal Rate of Return (IRR)	36%
financed by Bank Loan (18%, 2 yrs)	200,000		Incremental Gross Profit/Initial Investment	3.91x
Loan Principal and Interest due in 2yrs	240,000		Cash Flow/Total Debt Coverage	3.72x
vs Cash flows generated in 2 years	892,560			

5.2 Solar irrigation in Homa Bay county

Ms. Lilian Akinyi rents a farm in Homa Bay County near Luala Kambuya village. She was using a diesel pump to transfer water from a canal which is fed by the Sondu Miriu River. She hired the diesel pump one day a week for US $5.50, which included pump rental, petrol and transport. She irrigated 0.75 acre of tomatoes with the diesel pump and 0.25 acre of kale with a watering can. In September 2016 Ms. Akinyi purchased a Futurepump solar pump powered by a 80 Wp solar module and a 12-meter pipe (US $36) through Futurepump's Pay-As-You-Go program. She paid US $236 down, and will make a monthly loan payment of US $20 for 22 months. She stopped using the diesel pump as soon as she purchased the solar pump.

Fig. 8: Lilian Akinyi with her 0.75 acre maize crop, December 2016.

Ms. Akinyi no longer has diesel pump rental, fuel and transport costs, has increased her irrigated area from 1 to 1.25 acres, has added a maize crop (**Fig. 8**), and is irrigating more frequently than before. We assume she will increase to 1.5 acres by the second season after purchasing the solar pump. Using conservative estimates, her gross profit is projected to increase by 186% by her second season after purchasing the solar pump. A profit and loss analysis for Ms. Akinyi is shown in **Table 2**.

Table 2: Lilian Akinyi Profit and Loss Analysis

	Year 1 Actual		Year 2 Actual	Year 3 Projected
Lilian Akinyi Farm	**Season 1 (Pre-SWP)**	**Season 2 (Post-SWP)**	**Season 1**	**Season 2 (Post Loan)**
Farmer Profit and Loss Statement				
Acreage Planted	Tomatoes: 0.75; Kale 0.5	Tomatoes: 0.25; Kale 0.25; Maize 0.25	Tomatoes: 0.5; Kale 0.5; Maize: 0.5	Tomatoes: 0.5; Kale 0.5; Maize: 0.5
Total Yield (kg)	2,517	3,683	6,300	6,900
Yield change, %		*46%*	*71%*	*10%*
Total Revenues	**99,200**	**144,890**	**250,600**	**282,800**
Revenue growth %		*46%*	*73%*	*13%*
Operating Costs	29,530	38,063	50,246	52,700
Pump Fuel and its Transport	2,500	1,000	-	-
Pump Hire and Maintenance	3,000	3,700	1,500	1,800
Total Operating Costs	**35,030**	**42,763**	**51,746**	**54,500**
Gross Profit	**64,170**	**102,127**	**198,854**	**228,300**
Gross Profit Margin, %	*65%*	*70%*	*79%*	*81%*
Loan + interest payment (6 months)	-	15,000	15,000	-
Earnings Before Taxes (EBIT)	**64,170**	**87,127**	**183,854**	**228,300**
Debt Coverage and Investment Returns				
SWP Total Upfront Investment	78,600	5 Yr Return on Investment (ROI)		18.14
financed by own savings	23,600	5 Yr Internal Rate of Return (IRR)		197%
financed by Vendor Loan (10%, 2 yrs)	55,000	Incremental Gross Profit/Initial Investment		2.56x
Loan Principal and Interest due in 2yrs	65,000	Cash Flow/Total Debt Coverage		10.63x
vs Cash flows generated in 2 years	691,011			

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