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# TANZANIA MARKET SNAPSHOT

## Horticulture Value Chains and Potential for Solar Water Pump Technology

**MARCH 2019**

EFFICIENCY FOR ACCESS COALITION

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## Glossary

**Borehole:** Also known as drilled water well. It is a drilled vertical structure used to capture water from a water table held in the cracks of an aquifer – an underground layer of water-bearing permeable rock, rock fractures or unconsolidated materials (gravel, sand, or silt). The water can be brought up by manual means (e.g. buckets) or by mechanical or motor-driven pumps.[1]

**Canal irrigation:** Also known as channel or ditch. This irrigation system uses waterways to supply water to one or more farms. Field ditches have smaller dimensions and convey water from the farm entrance to the irrigated fields.[2]

**Correlation:** A statistical tool used to assess the degree of association of two quantitative variables measured in each member of a group (Aggarwal and Ranganathan, 2016).

**Correlation coefficient**: A number between −1.0 and +1.0 that expresses the degree of correlation between any two variables on a continuous scale (also known as Pearson's correlation coefficient or "r").

**Crop coefficient:** A dimensionless number that is multiplied by the potential evapotranspiration to obtain the actual crop evapotranspiration (See *Total Gross Irrigation Needs*). There are different coefficients for a single crop, depending on the stage of plant growth.[3]

**Diesel (fuel) pumps**: These are motorized devices, with capacities ranging from 3.5 to 6.5 horsepower (hp). The most common types are centrifugal (commonly used to draw water from surface bodies), turbine (for deep wells), submersible and propeller.[4]

**Drip irrigation**: In this method, water is applied either as a surface drip (i.e. directly above the root system of the plants) or as a subsurface drip (i.e. applied directly to the roots of the plant).[5] It is an effective delivery system that minimises evaporation. Other names: trickle or micro-irrigation.

**Effective rainfall**: Proportion of the total rainfall that is stored in the soil for later use by the plants.[3]

**Evapotranspiration:** Water lost through a combination of transpiration from plant leaves and evaporation from soil and wet leaves[5] (see *Total Gross Irrigation Needs*).

**Free-on-board:** The value of the goods plus the value of the services performed to deliver the goods to the border of the exporting country

**Hand-dug wells**: Holes dug in the ground, manually constructed using shovels, picks, etc. Their typical depth is between eight and 20 metres.[6]

**Manual irrigation:** In these systems, containers, watering cans, buckets and other devices are used to carry water from the water source to the fields.

[1] https://wikiwater.fr/E28-Various-types-of-wells-and-boreholes-General-points
[2] http://www.fao.org/3/r4082e/r4082e06.htm
[3] http://irrigation.wsu.edu/Content/Resources/Irrigation-Glossary.php
[4] https://www.ag.ndsu.edu/publications/crops/irrigation-water-pumps/ae1057.pdf
[5] https://www.maximumyield.com/definition/771/drip-irrigation
[6] https://wikiwater.fr/e29-hand-dug-wells

**Mechanical irrigation:** Hand operated devices with are human-powered. The most common mechanical devices are treadle pumps, such as MoneyMaker pumps[7], hip pumps and concrete peddle pumps. These systems can draw water from hand-dug wells, rivers, streams, lakes and ponds (Keraita and de Fraiture, 2012).

**Pearson correlation:** The Pearson correlation assumes a linear relationship between variables. Results range from -1 to +1 inclusive, where +1 denotes an exact direct linear relationship—that is, as x increases, y increases. A negative correlation denotes an inverse relationship, e.g. as x increases, y decreases.

**Rainfed crops:** Refers to crops grown without use of any irrigation system (including manual irrigation)

**Strong/weak correlation:** Because correlation is an effect size and our goal was data exploration—as distinct to proving particular hypotheses—we estimated the strength of the correlation following the guide of Evans (1996), where values below 0.39 are "weak", and values above 0.60 are "strong".

**Vegetables, fresh**: In the absence of FAOSTAT price, yield and volume data for the following crops as separate commodities, in this report we used the ' Vegetables, fresh' classification to group the following items: African eggplant, amaranthus, carrot, corn/maize, cornflower, cucumber, okra, plantain, pumpkin, squash, sweet peppers, spinach, watermelon and leafy greens.

**Vegetables, leguminous**: A FAOSTAT category that includes chickpeas, lentils, peas, soybeans, beans (dry) and broad beans (*Vicia faba)* for shelling.

**Total gross irrigation need (TGIN)**: In the context of this report, it is defined as the flow of water (Litre/hour) needed to meet crop[8] water needs of an entire scheme minus the effective rainfall, divided by the irrigation efficiency. It can also be defined as the continuous flow of water required for good crop production during the irrigation season.[9] This term is calculated using the following equation:

$$TGIN = [A_{irr} * \ [(ETo * Kc) - E\_r \ ]/E\_Irr$$

Where $A_{irr}$ is the area irrigated (in square meters), *ETo* is the reference crop evapotranspiration in metres per hour, *Kc* is the average value of the crop coefficients[10] (dimensionless) per hour, *E_r* is the effective rainfall (in metres), and *E_irr* is the irrigation efficiency (%).[11]

**Use case**: Examples (not requirements) of the interaction between actors and systems to achieve some set objective. In this case, the actors are farmers interacting with irrigation systems.

[7] http://moneymakerpumps.org/

[8] For the purposes of the calculation of TGIN and given the data constrains of CropWat, we categorised the 22 crops declared by farmers in our sample (listed in Figure 3) in four groups: a) tomato (considered a high-volume product), b) cabbage (high volume), c) roots/tubers—which in the sample surveyed only encompasses sweet potatoes and it is also considered high volume—and d) other vegetables, which may be considered high value.

[9] http://www.fao.org/3/u5835e/u5835e04.htm

[10] Calculated by linear interpolation between the Kc values for each crop stage.

[11] In all cases, *E_r* was considered to be 100%. That is, the calculation of TGIN does not consider irrigation efficiency factors because of the wide range of conveyance and delivery systems used by farmers; TGIN only represents the 'bare' water needs to grow the crops.

## Acronyms and abbreviations

CAGR: Compound annual growth rate (%)

CAPEX: Capital expenditure

DFIs: Development & finance institutions

FAO: Food and Agriculture Organization

FGD: Focus group discussion

FOB: Free-on-board

GDP: Gross domestic product

GIZ: Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH

ha: Hectare

hp: Horsepower, a unit of energy in the British system

IFAD: International Fund for Agricultural Development

JICA: Japan International Cooperation Agency

KSHS: Kenyan shillings

N: Number of observations (sample size)

NGO: Non-governmental organization

$\bar{r}$ : Coefficient of correlation

SWP: Solar water pump

Std. Dev: Standard deviation

TGIN: Total gross irrigation needs (litres per hour)

T SH: Tanzanian shilling

UNDP: United Nations Development Programme

USAID: United States Agency for International Development

US$: United States dollar

WFP: World Food Programme

## BACKGROUND

**Forty percent of the global population relies on agriculture as its main source of income, yet access to water remains an ongoing struggle for many. Cost reductions for SWPs have the potential to make modern irrigation accessible and cost-effective for nearly 500 million small-scale farmers worldwide.**

The UK-funded Low Energy Inclusive Appliances (LEIA) Programme identified solar water pumps as one of its priority products due to their immense potential for productive use and agricultural productivity.

In March 2018, the Efficiency for Access Coalition (the Coalition) convened a Solar Water Pump Market Development Roundtable in Nairobi, Kenya. The event brought together over 40 industry leaders who identified 30 actions for the Coalition to take forward. The top priority that surfaced was to "conduct research to size the total addressable market and segment by geography, customer type, and willingness to pay." This report was designed to address this research need.

The geographic focus of the report is Tanzania, but it is envisioned that the methodology can be replicated in other emerging solar water pump markets and there are learnings that are applicable to the market more broadly. In the coming years, the Coalition will undertake more research to address the needs of market stakeholders, including global market sizing and additional research to better understand the customers' needs and the socioeconomic impacts.

# 1 Executive summary

## 1.1 About this study

This study unearths new market intelligence on irrigation patterns in the Tanzanian horticulture sector. It fills important gaps on the adoption of solar irrigation technology and provides actionable insights for actors looking to increase adoption of solar water pumps (SWPs) in Tanzania and beyond. Its purpose is threefold:

i. Characterise a sample of 407 farmers in three agricultural regions of Tanzania

ii. Size and characterise the market for SWPs and potential customers

iii. Develop a set of strategic guidelines that catalyse the market for SWPs

The Tanzanian horticulture sector is a small but dynamic agricultural segment, with exports valued at US$591 million in 2016 and an annual growth rate of 9 to 12% per annum (Cambridge Economic Policy Associates Ltd, 2016; MatchMaker Associates, 2017) Previous reports have highlighted the opportunities of solar irrigation unlocked by the high levels of solar radiation throughout the year and across the country (AHK Kenia, 2016; Holthaus *et al.*, 2017; Hartung and Pluschke, 2018).

To understand and characterise the market for SWPs, primary data were collected from 67 key stakeholder interviews, 81 focus group discussions and 407 individual farmer surveys. The study's geographical reach included three important horticultural regions:

- Arusha and Kilimanjaro regions (Arusha – Kilimanjaro);
- Morogoro and Iringa regions (Morogoro – Iringa); and
- Singida region.

Data collected included geographic location, farm size, types of irrigated crops planted, current usage & preferences in irrigation systems, capital and operative costs, attitudes to financing mechanisms, and obstacles to growth. Some of these factors were selected to develop a market segmentation method. These findings were then used to understand the elements that are pre-conditions for adoption of solar water pumps. A method to develop value propositions for different farmer segments was also determined.

## 1.2 Key findings

### Understanding potential users

- Sixty-nine percent of the farms surveyed are below 2 hectares. The average head farmer has completed primary studies (92%), carries out some level of horticulture commercial activity (98%), and sells on average 71% of the farm's produce (as opposed to household consumption), mostly at farm gate (43%) or in their local market (21%).
- Sixty-nine percent of farmers sell their produce during the dry season, when the crops reach their highest prices (Mayala and Bamanyisa, 2018). Water for irrigation is available throughout the year for 72% of the farms surveyed, typically from surface sources (e.g. rivers, streams and lakes) (53%) and hand-dug wells (36%). Seventy-seven percent of the farmers interviewed hire extra labour to attend the farm, which carry out an average of 54% of the cropping activities. Finally, 50% of head farmers engage in off-farm activities for generation of extra income.

### Farmers' use cases: Irrigation area, crops, requirements, source of water, depth, and distance to water source

- In this survey, as well as in previous Tanzanian surveys (Keraita and de Fraiture, 2012; Ministry of Agriculture, 2017), the uptake of SWPs was found to be zero. Previous cases of deployments of SWPs in other countries indicate that explanations for the lack of uptake in Tanzania may include: low levels of awareness and familiarity with SWPs (IRENA, 2016; Hartung and Pluschke, 2018); the high level of initial investment, and the high risk associated to this capital item —including theft —; and iii) the lack of viable financing options for SWPs.
- Forty-one percent of the farmers interviewed use manual (buckets) systems and 2% rely on rainfed crops. Diesel pumps (36%), canals (18%) and mechanical pumps (2%) are second, third and fourth choices, respectively.
- From a technical point of view, the selection of a particular irrigation system by farmers is a multi-factorial choice based on geophysical parameters. For example, manual irrigation correlates to the use of hand-dug wells, which in turn correlate to the largest gross irrigation needs. Similar dependencies were drawn for

diesel pumps correlating with hand-dug wells and surface water sources, high irrigation needs, and large irrigated areas. To ensure optimum design of SWPs for horticulture, recognition and understanding of these interactions is important.

- Farms using canals and diesel pumps as irrigation systems combine the largest irrigation areas, the highest irrigation needs and the highest estimated horticultural incomes in the sample surveyed. A likely explanation is that some farmers with canal access also own a diesel pump, which enables them to extend water availability during dry seasons, leading to higher production. These irrigators present a good profile for SWP adoption. Mechanical, manual and rainfed irrigators present significantly lower incomes than the former group.
- The potential of increasing irrigated areas through transition to improved irrigation technologies is latent. This potential—defined as the percentage difference between total farm area and irrigated area—is highest for users of rainfed systems (75%) and for manual irrigators (62%).[12]

### Financial factors in selection of irrigation systems

- In Tanzania there are barriers for farmers to access institutional loans and financing mechanisms, which can be traced back to farmers' socioeconomic factors, the scarce instruments offered by financial institutions and other factors. For example, stakeholders interviewed in Dodoma, Tabora and Singida consistently indicated that there are no commercial sources of financing for irrigation equipment (or any other farm expenditure) readily accessible by farmers.
- Low income associated with horticulture can be caused by the choice of inefficient irrigation systems, whilst the same factor can also drive farmers to adopt inefficient, low cost irrigation means (e.g. rainfed systems). Breaking this cycle will require stronger interventions than facilitating substitution with other irrigation technologies such as SWPs.
- Diesel pumps are the second most used irrigation technology in our sample, which indicates that the extra capital required to buy these—as compared to cheaper mechanical or manual alternatives—is not an unsurmountable hurdle for the uptake of better pump technology. Therefore, the high investment for SWPs—often mentioned as the main barrier to adoption—should not be seen as an intractable situation, as long as other purchase factors are met.
- Farmers growing most crop types have similar incomes and are spending similar amounts in purchasing irrigation equipment.
- In our sample, 56% of farmers across all irrigation technologies were dissatisfied with their irrigation system. Fifty percent of diesel pump users reported being dissatisfied. In the latter case, the high dissatisfaction could be partly attributed to operational costs, which may open a point of entry for SWPs.

### Factors influencing pruchase decisions for irrigation technology

- We detected eleven key factors of purchase for irrigation systems. The top five factors in terms of the number of mentions by farmers were: cost and affordability (31% of sample), availability of the equipment and inputs (19%), water source availability (12%), simplicity of use (10%), and awareness about other irrigation technologies (6%). A sixth category was formed using two technical purchase decision parameters; irrigation area (5%) and reliability/efficiency of the irrigation solution (5%).
- Based on the six groups above, we developed six farmer typologies that correlate well with irrigation characteristics. These were: the cost-driven farmer, the distribution-reliant farmer, the water conscious farmer, the effortless farmer, the unaware farmer and the technical farmer.

### Market potential, segmentation and strategy

In this study, the market size for all types of irrigation technologies in Tanzania was estimated to be US$86.2 million in 2018 and expected to grow to US$151.3 million by 2022. As relatively new entrants, SWPs will need to carve a market share out of existing and established irrigation options (e.g. canal irrigation, diesel and mechanical pumps).

We developed two a-priori segmentation methodologies based on market orientation and irrigation technologies. These two approaches indicated a more or less homogeneous horticultural market for irrigation systems.

We therefore used the farmer typologies previously developed to provide a potential basis to segment the market. Having said this, future market research work for SWPs should be performed in other agricultural sectors

[12] In the context of this report, 'irrigated area' refers to farmers that actively irrigated with means other than rain. Note that farmers had the option of selecting more than one irrigation system in use; some farmers using rainfed systems also declared other irrigation system, thus bringing down the percentage difference from the expected 100% to 75%.

(e.g. dairy, grains, livestock production), as it is likely that horticultural applications could effectively be treated as a single-segment market.

The most receptive points of entry for SWPs were detected in the following groups:

- **According to purchase drivers:** The technical farmer & the distribution-reliant farmer (2018 combined market size: US$25 million), which overlaps with the diesel pump switchers in bullet point three below and the three main categories of farmer market orientation.
- **According to farmer market orientation:** Commercial farmer & market oriented farmer (2018 combined market size: US$59.8 million).
- **According to irrigation technology:** Diesel pump users & canal irrigation users (2018 combined market size: US$46.4 million). For farmers using both (i.e. canals for rainy seasons and pumps for dry seasons), the point of entry is the substitution of diesel pumps by SWPs, initially as a seasonal option and eventually as the all-seasons option.

## 1.3 Recommendations

**We recommend that individual manufacturers and distributors of SWPs address the following.**

- **Cost/affordability** was the top purchase decision detected in this study. We recommend that companies, manufacturers and distributors:
    - Carry out market research to detect the purchase price point for different groups;
    - Carry out a detailed analysis of operational expenditure as compared to SWPs; and
    - Design credit/financing mechanisms that bring the annual payments of SWPs in line with the levels of annual capital and operating expense for competing technology.
- **Availability of equipment and inputs** was the second most important purchase. In order for SWPs to diffuse successfully throughout markets, SWP supply chains must meet farmers near their farms and provide or link customers to spare parts suppliers.
- **Simple, easy to use equipment** was also a significant purchase decision driver. Appropriate design by manufacturers and packaging by distributors is therefore essential. Training farmers and their suppliers on how to use their equipment, and developing the capacity of on-the-ground staff to attend to technical and marketing queries are also important.
- **Awareness** of solar pump technology is extremely low and uptake is non-existent in our farmer sample. Significant marketing efforts and campaigns that educate potential buyers to will be important to prepare territories for sales. Campaigns should also be extended to the preferred local/regional suppliers and spare parts stockists.
- **Value proposition** statements should be modelled around the following points: affordable irrigation solution with accessible financing mechanisms, minimum operational costs, an extended sales & service network, training, simple operation and equal or better reliability and irrigation performance than competing technologies.
- SWP companies should also consider the addition of **complementary products**, such as drip irrigation equipment. This strategy has been shown to work in other regions (Hystra, 2017; CEEW, 2018a; Hartung and Pluschke, 2018).

**Finally, there are a number of additional actions that can be taken to catalyse the SWP market for all players, including:**

- **Awareness:** Development of permanent demo sites, programs and awareness campaigns
- **Knowledge and capacity building:** training, train-the-trainer and ongoing support.
- **Consumer credit:** farmer-friendly financing is central to affordability and perception of cost
- **Accessibility or availability of solution:** well-developed supply chains for SWP equipment, possibly including a network of distributors of equipment and spares when possible.
- **Agronomic support:** input supply and advice, agronomic capacity and market access support.

Given that there is no common industry association or umbrella organization that can undertake overarching activities on behalf of the SWP industry, it is up to the individual companies to determine their own level of preparedness to tackle one or more of these activities, and the time horizon to achieve these.

# 2 Introduction

The application of solar technologies in Tanzania is a natural fit to the country's high solar radiation power (4–7 kWh $m^{-2}$) distributed over 2,800–3,500 sunshine hours per year (AHK Kenia, 2016). Solar power is the dominant electricity source in rural households for domestic purposes (National Bureau of Statistics, 2017), with solar products (i.e. lighting, kits and panels) estimated to have a market penetration of 16% (Ipsos Tanzania, 2017). Supporting policies, including the exemption of import duty and VAT on some solar components, e.g. panels, batteries, inverters and regulators (PwC, 2018), have assisted industry development.

Notwithstanding the positive outlook in the domestic (local) market, the uptake of some specialized solar applications such as solar water pumps (SWPs) has lagged behind other applications, particularly in the agricultural sector. This lag persists even though the cost of solar components has decreased and the availability of financing for renewable energy has increased, making SWPs a viable alternative for both large- and small-scale irrigation schemes (Hartung and Pluschke, 2018).

The technology applied in SWPs is based on photovoltaic principles, converting solar energy into electrical energy to run a direct or alternating current motor-based water pump (Chandel *et al.*, 2015). At a global level, 60% of the market value of SWPs is generated by agricultural applications (Grand View Research, 2016).

In Tanzania, uptake of solar irrigation has been promoted in the past through initiatives such as the Water Sector Development Program (2007-2014), where some investment focused on solar technologies (Welsien, 2015). Further, the United Nations Development Programme (UNDP) has funded no less than 13 demonstration projects focused on the use of SWPs for small-scale irrigation, particularly around Lake Victoria (The World Bank, 2016).

Despite these efforts, previous Tanzanian surveys (Keraita and de Fraiture, 2012; Ministry of Agriculture, 2017) have reported zero uptake of SWPs for irrigation purposes. Observations from several case studies of SWP deployments in other countries can provide some reasons that explain the low penetration rate of this technology in Tanzanian agriculture:

- Low levels of awareness and familiarity with SWPs (IRENA, 2016; Hartung and Pluschke, 2018).
- The high level of capital expenditure required as initial investment, and the risk associated to it, including theft (Hartung and Pluschke, 2018). This issue may particularly discourage smallholders that have limited resources invested in a fast-moving product, such as perishable fruit and vegetables.
- High tax and import costs, e.g. taxes, custom clearances13, on parts or equipment necessary to develop a local SWP industry. Both may impact availability and affordability of SWPs (GIZ, 2015).
- Financing options for SWPs are either not available or unaffordable, especially for farmers who do not own land (Holthaus et al., 2017).
- A lack of advisor networks to assist farmers in selecting the appropriate irrigation technology (World Future Council, 2017).
- A lack of skills and know-how regarding the operation and maintenance of SWPs, and irrigation in general (World Future Council, 2017).
- Although many of these issues are common in countries that are expanding the use of SWPs for irrigation, it is also necessary to obtain local, in-market research to target the specific needs and factors of influence for adoption and use of irrigation technologies (solar and others) by the end user in Tanzania (Katikiro, 2016).

## 2.1 Objectives, terms of reference and knowledge needs

The main objectives of this study are to unearth new market intelligence collected on-the-ground and at a farmer level and to fill information gaps on the adoption of irrigation technology in Tanzania, with a special emphasis on SWPs. The specific outcome sought was to provide actionable insights for the SWP sector and other market players, focused on how to accelerate SWP adoption. Pivotal components of this study were the development of a market segmentation methodology, market and segment sizing, and the development of value propositions for farmers.

The in-market intelligence and research needs detected for this project are presented in Table 1.

## 2.2 Organisation of the report

The remainder of this report is organised as follows:

[13] Although some imported solar components are legally exempted from customs duty and VAT in Tanzania, reforms in 2015 removed the exemption in a number of important components. Further, the application of the exemption regime can be haphazard (GIZ, 2015).

- **Section 2** provides contextual information about the agricultural irrigation sector in Tanzania, the role of solar irrigation, the regulatory framework surrounding the application solar irrigation and the selection of horticulture as a segment of focus for the analysis.
- **Section 3** details the strategy for primary and secondary data collection, and methodological approaches for subsequent quantitative and qualitative analyses.
- **Section 4** includes a general description of farm activities and socio-economic characteristics of the farmers surveyed in this study.
- **Section 5** describes six key variables[14] used to understand farmer irrigation needs and corresponding SWP solution requirements.
- **Section 6** describes the three multi-level factors[14] as main themes: a) the type of irrigation system; b) the water source; and c) the factors that influence purchase decision of a particular irrigation technology over others. Some considerations about financial mechanisms are also presented.
- **Section 7** presents an estimation of the market size for all irrigation system types in Tanzania.
- **Section 8** discusses the segmentation approaches used to define the potential strategies for promoting SWP uptake.
- **Section 9** presents a proposed market strategy, based on the farmer typologies developed in Section 8.
- **Section 10** provides concluding remarks and recommendations for future work.

[14] These variables can be understood as the dependent variables, or the responses that we used to evaluate the effect of the three multi-level factors.

*Table 1. Area of inquiry, key knowledge need and needs per market player*

| Area of Inquiry | Knowledge gap | Needs per market player |
|---|---|---|
| What are the most useful ways to segment farmers for pump adoption?<br>What questions should be asked to allow SWP companies and distributors to segment potential customers?<br>What customer and geographic pre-conditions are needed to make solar water pumping a viable solution?<br>What is the current market size of each segment and what is its potential?<br>How can this market sizing be replicated in other regions? | Potential users and their locations | Distributors need to know who to target, with what products and how to find them.<br>Development & finance institutions (DFIs) and non-governmental organisations (NGOs) need to know which type of farmers can benefit to determine whether or not to promote. |
| | Farmers' use cases, e.g. irrigation area and requirements, source of water, depth and distance to water source. | Manufacturers need to know design parameters.<br>Distributors need to know the models they should stock based on inventory or demand estimates.<br>DFIs & NGOs need to know where and what kind of support farmers need to adapt the technology. |
| | Segments, market size and value proposition, e.g. the most useful ways to segment farmers for pump adoption. | Manufacturers need to know the comparative size of each segment in order to develop a strategy for each.<br>Suppliers need this information to plan purchases per segment.<br>DFIs, NGOs and policy makers need to know if market interventions are required. |
| What factors—e.g. quality, efficiency, price, business opportunity and social influence—do potential customers consider when purchasing an irrigation solution, particularly SWPs?<br>How do consumers value capital expenditure vs. operational and other factors when choosing between diesel/petrol pumps and SWPs?<br>What are consumers preferred method for financing SWPs?<br>What are companies offering in terms of payment mechanism? | What potential adopters care about most when making a purchasing decision? | Manufacturers will emphasize different designs based on this information.<br>Distributors will source and offer different packages to match preferences.<br>DFIs and NGOs will know where to apply their external influence. |
| | Detailing any current negative consumer perceptions—e.g. affordability, previous experiences with other irrigation systems—that the industry needs to address for successful adoption. | Manufacturers and distributors will need to adjust strategy to address any misperceptions.<br>Policymakers and NGOs may need to generate awareness and educate to address misperceptions. |
| What are the customer and geographic pre-conditions that are needed to make solar irrigation a viable solution? | Enabling factors for the uptake of SWPs. | NGOs, Policy Makers, DFIs to support Mechanisms required to increase awareness and promotion.<br>Distributors need to understand what other services can support the introduction of SWPs, and the profile of farmers that may present fewer opportunities for introduction. |
| With whom are farmers working currently, by segment (suppliers, buyers, groups, NGOs)? | Networks/groups favoured by farmers to receive trusted information about inputs/supplies. | All parties will know what awareness/marketing channels can be used.<br>NGOs will know where they fit in the information chain. |

# 3 Background

## 3.1 Irrigation technologies and agricultural productivity

- Tanzania has over 4.7 million agricultural operators (all types), which can be classified into four categories based on market orientation[15]:
    - Subsistence: none-to-occasional commercial activity, low level of farming sophistication.[16]
    - Loose market oriented: low level of consistent (continuous) commercial activity, low level of sophistication.
    - Market oriented: medium to high level of consistent commercial activity, medium level of sophistication.
    - Commercial: fully oriented to consistent commercial operation, medium to high level of sophistication.
- There are no recent assessments of the proportion of farmers in these market orientation categories.
- There are over 400,000 irrigation operations in Tanzania (Ministry of Agriculture, 2017). Established irrigation technologies include:
    - Manual systems (44% of total irrigation operations): buckets, watering cans and other container types.
    - Mechanical systems (17%): treadle and hip pumps, e.g. MoneyMaker systems.
    - Canal systems (35%): gravity- or stream-fed.
    - Petrol/diesel pumps (an estimated 4%).
    - Finally, an additional 4.3 million crop operations rely solely on rain, i.e. no irrigation.

The selection of irrigation systems and practices significantly impacts agricultural productivity. For example, smallholder irrigated farms have two to three times higher yields than rain-fed farms (Agrawal Shalu and Abhishek, 2018). Small-scale irrigation technology presents excellent internal returns on investment—in some cases as high as 28% (You *et al.*, 2010). Further, research has shown that pressurised drip irrigated vegetable plots produce higher yields and higher returns than manual means (Woltering *et al.*, 2011).

Several studies also indicate that the adoption of modern irrigation technologies move farmers from subsistence to market-based, commercial production, partly achieved through the improvement in yields and crop quality (Perfect *et al.*, 1986; Burney and Naylor, 2012; de Fraiture and Giordano, 2014; Mwangi and Crewett, 2019). Additionally, once a farmer has adopted irrigation, he/she is likely to implement other productivity-enhancing measures, including farming higher-value crops and expanding cropped areas. Irrigated farms also exhibit an increased resilience to climate change and pests/diseases (Turral *et al.*, 2011; Ministry of Agriculture Food Security and Cooperatives, 2014).

Modern irrigation technologies can substantially enhance the value of Tanzanian agriculture, an already important economic sector that accounts for 25% to 29% of the total national gross domestic product and provides jobs to 76% and 67% of the rural and national workforce, respectively (FutureWater, 2012; The World Bank, 2012; Ministry of Agriculture Food Security and Cooperatives, 2014; National Bureau of Statistics, 2016; Bank of Tanzania, 2017).

[15] These definitions were used in the survey for the classification of farm operation in terms of market orientation. For an in-depth discussion of farmer typology, see: *Pienaar, P. L. (2013). Typology of Smallholder Farming in South Africa's Former Homeland: Towards an Appropriate Classification System. Thesis for the Master of Science in Agriculture (Agricultural Economics). Stellenbosch University.*

[16] Low levels of farming sophistication are referred to the use of labour-intensive cultivation and irrigation techniques.

## 3.2 The role of solar irrigation

**The use of SWPs for agricultural irrigation presents the following advantages over other options:**

- SWPs are reliable irrigation systems in remote areas, particularly when grid power is erratic or not available, or during periods of fuel scarcity or price volatility (Hartung and Pluschke, 2018). Low rural household electrification rates in Tanzania (16.9%) also present a strong value proposition for SWPs (National Bureau of Statistics, 2017).
- SWPs have higher capital costs and lower operating costs than competing pump technologies. The payback for SWPs is 4 to 6 years (Chandel et al., 2015; Grand View Research, 2016), while the payback for a diesel pump is less than a year (ILSSI, 2017). However, the life cycle cost of a diesel pump can be up to six times more than the life cycle cost of a SWP (Welsien, 2015). Results from the deployment of SWPs in Bangladesh indicate that farmers can save up to 40% of irrigation expenditure as compared to diesel pumps (World Future Council, 2017).
- In terms of replacement, the life span of diesel pumps is approximately 7 to 12 years[17], whereas the life span of solar panel modules—which are the most delicate components in SWPs—is between 20 to 25 years (Desert Research Foundation of Namibia (DRFN), 2008; Chandel et al., 2015).
- The combination of SWPs, drip irrigation and water conservation methods (e.g. mulch) substantially increase water use efficiency, thus enabling irrigation of larger production areas with the same amount of water and therefore increasing profitability for smallholder farmers (Everaarts, 2011; Liheta Consulting Services, 2017).
- SWPs for surface use (as distinct to submersible pumps) can be moved from area to area, providing added flexibility for farmers with multiple irrigated fields.
- SWPs are more productive when solar radiation increases, which coincides with the highest water demands for crops.

The use of solar irrigation has also been highlighted as a technology that can reduce vulnerability to changing rainfall patterns as a result of climate change (IRENA, 2016). The Tanzanian Agriculture Climate Resilient Plan 2014–2019 included actions—specifically, the development of financial mechanisms and incentives—to encourage the uptake of farmer-led, sustainable irrigation technologies (including wind and solar water pumps). The plan targeted smallholder farmers located in semi-arid and drought-prone areas (Ministry of Agriculture Food Security and Cooperatives, 2014).

## 3.3 Horticulture as a focus of this study

Horticulture in Tanzania—which encompasses flowers, fruits, vegetables, seeds, spices and roots and tubers—is a small but dynamic agricultural segment, with exports valued at US$591 million in 2016[18] (Food and Agriculture Organization, 2018d) and an annual growth rate of 9 to 12% per annum[19] (Cambridge Economic Policy Associates Ltd, 2016; MatchMaker Associates, 2017; Food and Agriculture Organization, 2018d). The industry also generated US$477 million in domestic sales in 2014 (Mwandima, 2015). This indicates that the current total value of horticulture now surpasses US$1 billion.

The economic potential of Tanzania's budding horticultural sector needs to be placed in the context of an expanding global market for fruit and vegetables, currently representing US$390.8 and US$436.5 billion in sales, respectively (MarketLine, 2018). By 2022, the global demand of fresh fruit is expected to reach 600 million tonnes, while the demand for vegetables will reach 850 million tonnes (Euromonitor International, 2018). This potential growth places horticulture as a genuine opportunity of income diversification in the agricultural sector, particularly given the flagging markets for traditional export cash crops.

Horticulture is currently estimated to encompass 423,906 operators[20] (Ministry of Agriculture, 2017) employing over 500,000 people, approximately 65% of which are women (Cambridge Economic Policy Associates Ltd, 2016). Smallholder farms cultivating landholdings of less than 2 hectares represent about 70% of the horticultural operations (Mkindi, 2011; Monitoring African Food and Agricultural Policies, 2013).

Horticulture is an interesting case study to test the market for SWPs in the context of Tanzania's agriculture sector because:

- The irrigation needs are crop, climate and soil dependent, and cropping schedules cover both long and short rainy seasons. Horticulture therefore leads to a wide range of irrigation requirements, which may open more opportunities for SWPs.

[17] Note than life span of equipment can vary significantly from manufacturer to manufacturer.
[18] Reported as FOB (free on board, the value of the goods plus the value of the services performed to deliver the goods to the border of the exporting country).
[19] According to these authors 'calculations, the compound annual growth rate of horticultural exports stands at 10.8%, based on FAO export value data for fruit and vegetables.
[20] Excluding roots & tubers.

- The impact of irrigation technologies is maximised in crops with short-term cycles (i.e. less than one to three months) that require the high temperatures of the long dry season (when prices are higher), allowing horticulture irrigators to cultivate more than three crop cycles per year (Mwangi and Crewett, 2019).
- Published case studies found that Kenyan horticulture farmers who switched from diesel and treadle pumps to SWPs (financed through bank loans), were able to add 0.3 to 0.6 acres to their previous production area, and more than doubled their income (Holthaus et al., 2017). These cases suggest a significant impact of SWPs in horticulture operations.
- Horticulture is a smallholder-dominated sector, with direct links to subsistence farming. In Tanzania, women traditionally grow fruit and vegetable crops for their families.

# 4 Data collection and methodology

The guiding questions in Table 1 collectively convey the need to find undiscovered connections between the factors above, identify the SWPs target market segments and size, and understand what value propositions the industry can use to increase technology adoption in each of these segments.

## 4.1 Primary data collection

To achieve this study's objectives, primary data were collected from stakeholder interviews, focus groups and individual farmer surveys. The geographical reach of this study included five regions, selected for their significance in horticulture:

- **The Arusha and Kilimanjaro regions.** This area holds the largest potential for horticultural development, investment, production diversification and income generation.21
- **The Morogoro and Iringa regions**. Morogoro in particular was highlighted by stakeholders as having significant potential for horticultural intensification.
- **The Singida region.** This area has also been earmarked for future increases in its horticultural productivity, both for local markets and for regional exports to East African countries. This increased potential is mainly attributed to recent improvements in road infrastructure in the Central cluster.

**Primary data collection** investigated five topics of importance: a) socioeconomic characterization of farmers; b) dominant farming and horticultural systems in the area; c) markets and marketing structure; d) irrigation practices and technology; and e) enabling factors for the uptake of SWPs. We followed a multi-stage approach as illustrated in Figure 1.

**Stakeholder interviews** mainly included government officials at the regional and district level. Some input suppliers, agriculture experts, and representatives of NGOs were also interviewed. These interviews were conducted first and used to inform the farmer surveys.

The **identification and survey of farmers and horticultural groups in each region** was carried out through the information collected at district level (see Figure 1). Specific communities/villages with high horticultural production were identified at the regional, district and ward level. Information was elicited using three approaches: focus group discussions (FGDs), individual surveys, and informal interactions during demonstrations of SWP technology.

[21] TAHA, 2018. Personal communication during key stakeholder interviews.

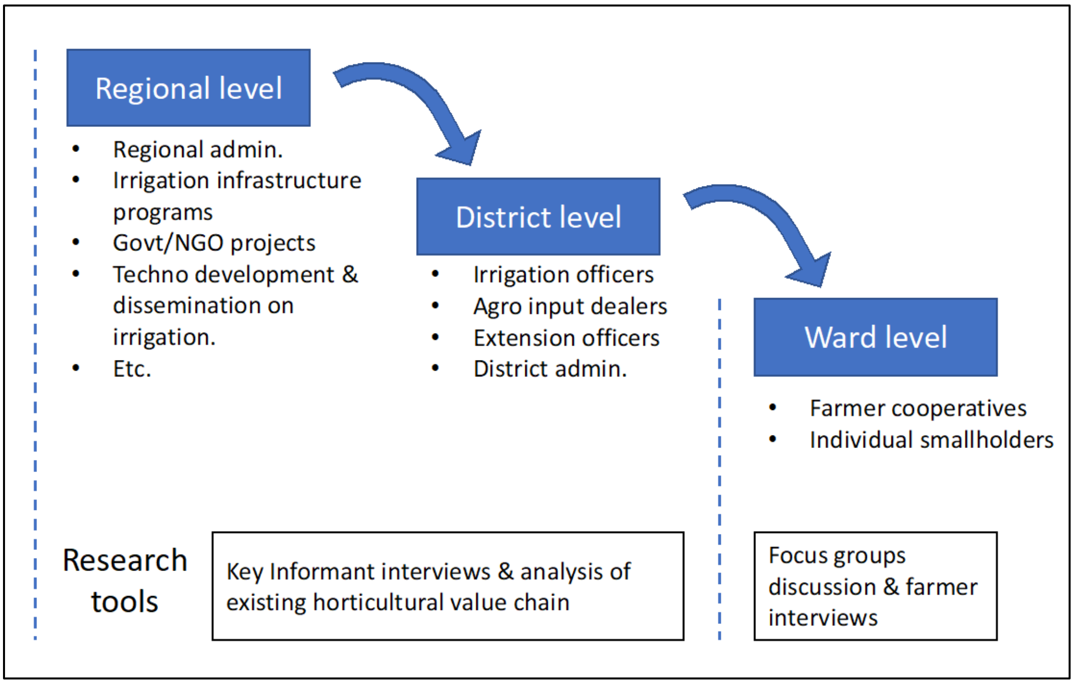



*Figure 1. Sampling sequence and application of survey tools*

## 4.2 Secondary data collection

A number of databases and tools were used to calculate irrigation needs per crop and location:

- FAOSTAT data was used to capture and analyse the production and price trends required to estimate farm incomes for vegetable growers (Food and Agriculture Organization, 2018d). These estimates were in turn used to calculate market forecasts for irrigation equipment.
- CropWat 8.0, a computer-based decision support tool developed by FAO, was used to estimate the water irrigation needs for the farm sample surveyed, based on soil, climate and crop data (Food and Agriculture Organization, 2018c).
- ClimWat, a FAO climatic database, was used in combination with CropWat to determine climate factors necessary to estimate irrigation needs (Food and Agriculture Organization, 2018a).
- FAO Crop Calendar, a tool that provides dates and seasons for optimum planting for different countries and agroecological zones, was also used (Food and Agriculture Organization, 2018b).

Additionally, a search for secondary sources including reports, articles and theses was undertaken to inform the collection of primary data, and to set the context for this report.

## 4.3 Sample characteristics and survey design

In this study, 67 stakeholder interviews, 81 Farmer Group Discussions and 407 individual farmer surveys[22] were applied across five regions, including 14 districts, 42 wards and 78 villages (Table 2 and Figure 2). Six people were trained to apply the surveys and lead the stakeholder interviews and FGDs.

[22] Individual farmers are a subset of FDGs

*Table 2. Number and proportion of stakeholder interviews, FGDs and individual farmer surveys*

| Area | Region | Stakeholder Interviews[23] | FGDs | Individual Farmer Surveys |
|---|---|---|---|---|
| Arusha-Kilimanjaro | Arusha (Arusha region, Arusha DC and Meru DC) | 14 (21%) | 9 (11%) | 44 (11%) |
| | Kilimanjaro (Kilimanjaro region, Mwanga DC, Moshi DC; Manyara included) | 23 (34%) | 18 (22%) | 90 (22%) |
| Singida | Dodoma (Dodoma City and Kongwa DC) | 8 (12%) | NA | NA |
| | Tabora | 10 (15%) | NA | NA |
| | Singida | 7 (10%) | 22 (27%) | 143 (35%) |
| Morogoro – Iringa | Morogoro, Iringa | 5 (7%) | 32 (40%) | 130 (32%) |
| **TOTAL** | | 67 | 81 | 407 |

Note: Percentage shown as a proportion of the total per column.

The stakeholder questionnaire contained 15 questions, most of them allowing open answers (Appendix 1). The format and style of the interview was flexible.

The FGDs were carried out in each village and directed to cover five topics of importance: a) dominant farming and horticultural systems in the area; b) markets and marketing structure; c) irrigation practices and technology; d) enabling factors for the uptake of SWPs; and e) schematics of the horticultural value chain. On average, each focus group comprised 20 farmers.

The individual farmer questionnaire contained 36 questions (Appendix 1), some of which were used during the FGDs. The focus was again on the key themes of this report, as described in Table 1.

### 4.3.1 Representativeness of the farmer sample

The sample size for the individual farmer surveys was calculated using standard methods (Cochran, 1977) and considered the number of horticultural operations, as established in Section 3.3, as the target population.[24]

From a geographical perspective, the five regions in Table 2 were specifically selected based on their high horticulture potential. Therefore, the farmer sample has an inherent bias. In horticultural surveys, this is a common occurrence simply because some locations have better agricultural conditions than others. The farms surveyed are located across five of the 10 agro-ecological zones in Tanzania, which provides sufficient climate, rainfall and soil diversity to test the case for SWPs under different irrigation needs. Additionally, the area formed by the polygon resulting from joining the most distant farms surveyed covers about 21% of the total Tanzanian surface and encompasses five of the six horticultural production hotspots detected in a previous study (MatchMaker Associates, 2017).

More importantly, all the farms selected for this study had an area smaller than 10 ha. This selection is reflective of the majority of farms in Tanzania, although the exclusion of larger players is reflected on the technology choices, capacity to purchase new equipment, attitudes to innovation uptake and other parameters of importance for SWPs.

[23] In Arusha-Kilimanjaro and Morogoro-Iringa all stakeholders interviewed were government representatives. In Singida, 76% were government representatives and 14% were commercial representatives.
[24] 95%, CI ±5%.

*Figure 2. Map of horticultural cluster in Tanzania (source: HODECT 2010 ) compared with the geographical distribution of the farmers included in this study*

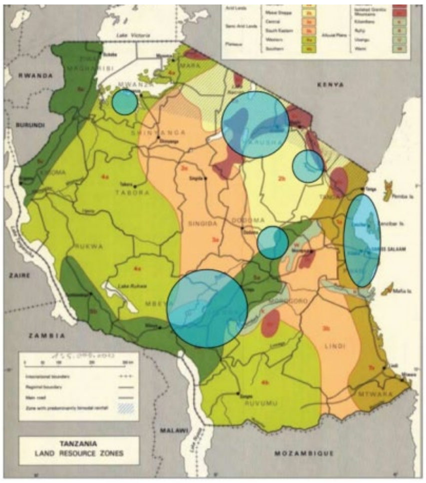
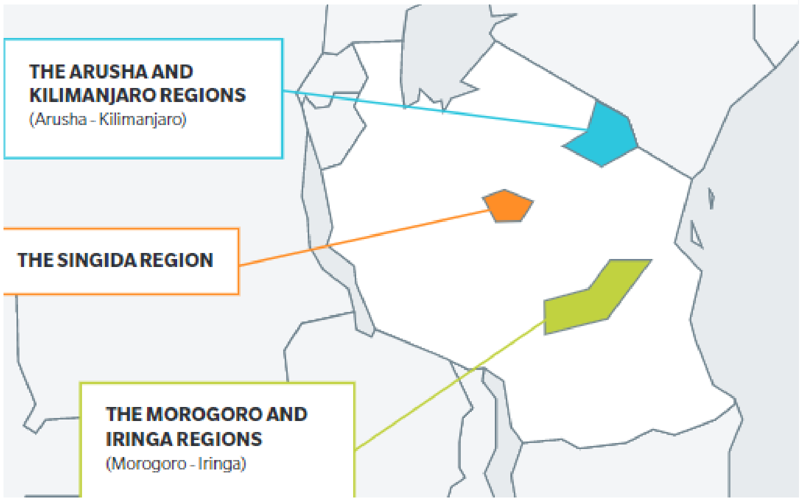


Figure 3. Horticulture Clusters in Tanzania




### 4.3.2 Limitations

- The results of this report are particularly robust for the vegetable farming segment, but less so for fruit, nuts and roots & tubers (including cassava, potato and sweet potato), due to an underrepresentation of these producers in the survey. However, some of the data sources, tools and methods used in this study enable modelling of key design and income parameters for the missing varieties. Regional climate variations can also be addressed in the same way. In this sense, the methodology is scalable to other crops.
- The FAOSTAT (2018) dataset for Tanzania is incomplete and only some of the selected crop data25 were found. Therefore, income and market size calculations are likely to be a conservative estimate.
- Finally, there may be some resistance among farmers to share financial information, such as costs, yields, income and any other information that may compromise their competitive advantages. Furthermore, farmers may not know or do not have this information readily available. It is expected that the results of this study are robust enough to withstand this uncertainty, although the financial variables presented need to be placed in this context.

## 4.4 Data analysis

The responses from the three data collection methods were put into spreadsheets and checked to ensure accuracy and consistency.

The analysis started from a rich and diverse pool of information: the individual farmer surveys provided specific data for 25 factors, including irrigation type (e.g. canal, manual and diesel), farm size, type of crop and climate, water availability and lifting needs, amongst others. User characteristics (e.g. demographics and market orientation), annual capital expenditure and purchase drivers for irrigation systems (e.g. cost and simplicity) were also collected (refer to Appendix 1, survey questions). Stakeholder interviews and focus groups worked in parallel to provide the necessary social context for horticultural irrigation.

The nature of the survey required two types of analyses, quantitative and qualitative.

### 4.4.1 Quantitative analyses

We performed preliminary basic descriptive statistics to characterise farms, farmers and the key irrigation characteristics (Sections 6 and 7).

Using the needs outlined in Table 1 as a guide, we used six key (dependent) variables to understand the effect of a) different types of irrigation technology; b) different types of water sources; and c) different purchase drivers in Section 7. These six single-response variables were: irrigated area, capital expenditure in irrigation systems, TGIN[26], depth of well (when used), estimated farm income from horticultural activities[28] and distance between

[25] FAO data categories included the following: green beans, peas, cabbages and other brassicas, onions (dry), tomatoes, potatoes, sweet potatoes, cassava, roots and tubers, garlic, vegetables (leguminous), yams, chilies and peppers, green maize, green vegetables (fresh).
[26] Variables calculated from a combination of primary and secondary data.

water source and field. We selected all variables and factors prior to data analysis, based on the information needs of the SWP industry when evaluating suitable pump models for farmers.

The six response variables were used to compare the effect of the three multi-level (independent) factors. This approach led to uncovering responses to specific questions such as:

- What is the impact of using diesel pumps, as compared to manual systems for irrigation on the farms' income?
- Is there a relationship between well users and the use of surface water bodies?
- Is cost a main factor in the purchase decision of an irrigation system?

For this analysis, we employed a data-driven analysis approach[27] using Pearson's correlation coefficients[28] to explore potential relationships between variables and factors (Taylor, 1990; Evans, 1996). The correlation coefficients were used to flag significant relationships[29] between variables, which were then tabulated and further analysed. Finally, meaningful insights were distilled from each section (6.1 to 6.3).

### 4.4.2 Qualitative analyses

We applied qualitative techniques for: a) open-ended questions from the individual farmer surveys that described the reasons driving the purchase of one irrigation system over others (Section 7.3); and b) individual surveys and stakeholder interviews that included relevant information about the pre-requisites for adoption of SWPs, also extracted from open-ended questions (Appendix 5). We employed word frequencies and extraction of phrases from relevant responses for our analysis.

To analyse the open-ended responses, we used Nvivo, a Qualitative Data Analysis (QDA) computer software package.[30]

### 4.4.3 Market potential and segmentation

When analysing Market Potential (Section 8), we first calculated the total market for all types of irrigation technology.[31] We used linear correlations to forecast the market data per crop (production, yield and price) for the period 2018–2022. The historical data (2000–2016), used as a basis for this forecast, was extracted from FAOSTAT to evaluate the total market size for irrigation systems. The historical and forecasted crop gross income was weighted by multiplying the average CAPEX percentage spent per crop.[32]

In the segmentation analysis (Section 8) the total irrigation market was split according to the segmentation method and characteristics, in order to narrow down the specific segment market value. Because of the characteristics of the farmer sample used in this study (i.e. mostly represented by vegetable production), the real market value is expected to be larger than our estimate once fruit (particularly orchard production), nuts and root vegetables (i.e. potato and cassava) are considered.

We developed two *a-priori* segmentation models: one used the commonly accepted market orientation approach, often used as a segmentation concept for farm services, inputs and technologies (Pienaar, 2013). Sixty-four percent of the stakeholders interviewed recommended this approach.

We based the second segmentation method on the farmers' incumbent irrigation technologies in Tanzania, considering that the SWP industry will need to gain market share by converting current users of established technologies to solar. We based this assumption on the insights gained during the stakeholder interviews, focus groups and the data exploration phase, where the lack of awareness on SWPs as options for irrigation was evident among horticulture farms surveyed.

We based a third segmentation approach on six farmer typologies, which were developed purchase driver analysis.

Quantitative data analyses were performed using MS Excel 2017, SPSS and Tableau 10.2.

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[27] As distinct from a hypothesis-driven approach.
[28] The Pearson correlation assumes a linear relationship between variables. Results range from -1 to +1 inclusive, where +1 denotes an exact direct linear relationship; that is, as x increases, y increases. A -1 correlation denotes an exact inverse relationship, e.g. as x increases, y decreases.
[29] Because correlation is an effect size and our goal was data exploration—as distinct to proving particular hypotheses—we estimated the strength of the correlation following the guide of Evans (1996), where values below 0.39 are "weak", and values above 0.60 are "strong".
[30] QSR International
[31] Throughout this report, "irrigation technology" and "irrigation system" are used to denote the range of options available to power water lifting and transport, be human, mechanical or other. We exclude piping, valves, drip tape and other elements that would configure a complete irrigation system.
[32] Calculation not presented in this report.

# 5 Farm and farmer characterization

Horticulture value chains in all Tanzanian regions can be broadly placed in a spectrum between smallholder subsistence farming and fully commercial farms.[33] In its most basic form, subsistence farming has a low/inexistent commercialisation level and is often inefficient because it relies on low-quality, low-yielding seed varieties; depends heavily on seasonal rains and faces inconsistent productivity. Subsistence horticulture also faces challenges in productivity, postharvest losses and inadequate access to finance. These are obstacles to the transition from subsistence to commercial farming.

Conversely, commercial horticultural farmers aim to supply high-value markets, such as supermarkets and export markets. They are focused at increasing yields, quality and profitability. Commercial farmers are well connected to their buyers and they are more resilient to market dynamics. Our farmer sample falls somewhere between these two extremes.

summarises the main characteristics of the farmer sample in this study.[34]

[33] Kakute/FA Research Consultant report: Regional and District Detail Information and Data. October 2018.
[34] Appendix 2 presents the full descriptive statistics of the farmer sample.

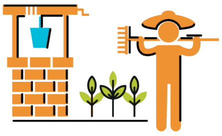
*Figure 3. Main characteristics of the farmer sample surveyed*

# FARMER CHARACTERISTICS

To characterize the market for SWPs in Tanzania, Efficiency for Access collected key market intelligence from 407 farmers, 81 focus groups, and 67 stakeholders in three regions. Typically, horticulture values chains in Tanzania can be classified into two categories: **smallholder subsistence** and **commercial**. Smallholder subsistence value chains are often inefficient, relying on low-quality, low-yielding seed varieties and rainfall for watering needs. Commercial value chains, on the other hand, supply high-value markets both domestic and international. The farmer sample of this study falls somewhere in between. Key characteristics are detailed below.

## FARM SIZE

Sixty-nine percent of all farms surveyed were below 2 ha (4.9 acres), confirming the view that smallholders dominate the horticulture sector (Mkindi, 2011; Monitoring African Food and Agricultural Policies, 2013).



**Smallhold farmers** dominate the horticulture sector in Tanzania.

**69%** of all farms surveyed were below 2.0 hectares.

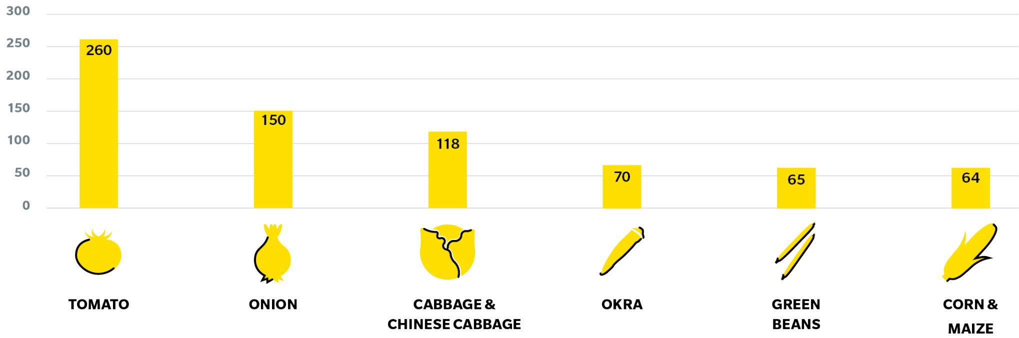
**3.38 hectares** Average farm size

**0.25 hectares** Smallest farm size

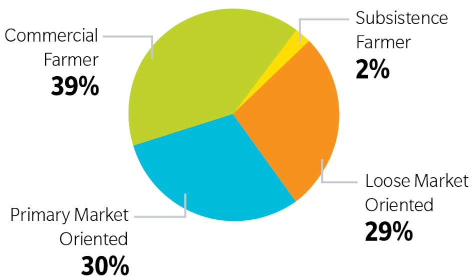
**17.0 hectares** Largest farm size

## CROPS CULTIVATED

For simplicity purposes, the listed items are the major horticultural crops grown, as declared by the farmers in the sample.




## FARMER TYPE

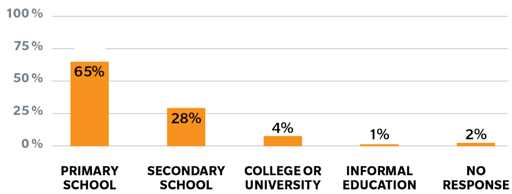



## HOUSEHOLD SIZE

**3.46 adults**

About 92% of the farms surveyed have between two and six adults living in the household.

## EDUCATION LEVEL




Note: N= number of observations; Std. dev= standard deviation; Min= minimum value detected in the sample; Max= maximum value detected in the sample.

## FARMER CHARACTERISTICS

### IN THE MARKETPLACE

**Percentage of Produce Sold**

**71%** produce sold

**29%** household consumption

The average percentage of produce sold per farmer type was: a) Commercial (76%), Primary market oriented (75%), Loose market oriented (63%) and subsistence (43%).

**Main Market Product**

**43%** of farmers sell products at farm gate

**20%** of farmers sell products at local market

Other points of sale include: wholesalers (13%), district markets (11%), urban markets (10%), other (2%), and processors (<1%)

**Main Sales Season**

**70%** of farmers sell produce during the dry season

**19%** of farmers sell produce during the rainy season

**11%** of farmers sell produce during both seasons

70% of farmers are selling their produce in the dry season, when produce reaches its highest prices (Mayala and Bamanyisa, 2018). Planting schedules for several crops often fall between rainy and dry seasons, because the crops also need the warm temperatures of the dry season.

**Labor Hire**

**77%** of farmers hire extra labor for farm activities

**Off-Farm Status Income**

**50%** of farmers pursue off-farm income

Most farmers hire extra labour for farm activities, indicating good job creation potential in the horticulture industry. This is interesting when compared with the off-farm income, which shows that about 50% of farmers pursue off-farm income. Therefore, only about 27% of the farmer sample that hire labour are fully dedicated themselves to their farms, with no other source of income.

### TECHNOLOGY USED

| MANUAL | DIESEL | CANAL | NONE | MECHANICAL | OTHER | SOLAR |
|---|---|---|---|---|---|---|
| **188** farmers | **163** farmers | **84** farmers | **10** farmers | **8** farmers | **6** farmers | **0** farmers |

# 6 Key irrigation characteristics

In this Section we provide an initial characterisation of the six key variables (also discussed in Section 4.4.1): irrigated area, CAPEX, depth of well, distance to the water source, TGIN, and estimated income from horticultural activities. Table 3 provides descriptive statistics of the six key variables described above.

*Table 3. Descriptive statistics of the six key variables for the entire farmer sample[35]*

| | N | Min. | Max. | Mean | Std. Dev.. |
|---|---|---|---|---|---|
| Irrigated area (acres) | 407 | 0 | 17.0 | 1.8 | 1.8 |
| CAPEX (T SH) | 407 | 0 | 5,000,000 | 177,462 | 371,617 |
| Depth of well (m) | 203 | 0 | 180.0 | 10.8 | 21.3 |
| Distance between field and water source (m) | 407 | 0 | 10,000.0 | 383.6 | 1,074.4 |
| TGIN (L/hr) | 407 | 0 | 22,680 | 2,160 | 2,880 |
| Horticultural income (T SH million) | 407 | 0 | 51.8 | 5.1 | 5.4 |

Some specific observations for each of these variables is presented in the next sections.

## 6.1 Irrigated horticulture area

Ninety-nine percent of farmers in our sample irrigate their crops. Of these, 47% of the farmers surveyed irrigate plots of 1 acre and below, whilst 8% irrigate areas of 5 acres and above. For farms where active irrigation took place, the irrigated horticultural areas represented on average 51% of the total farm area. The reasons as to why the rest of the farm area was not used for horticulture were not explored, although it is possible that the non-irrigated areas are being used for animal husbandry, cultivation of non-food crops and other activities. It is also possible that non-irrigated areas indicate insufficient capacity to irrigate the total farm area. If the latter is the case, this gap represents an opportunity for expansion of SWPs.

## 6.2 Capital expenditure in irrigation technology

A majority of farmers (88%) spend an annual CAPEX of T SH 500,000 (US$214) or less. Farmer data analysis and stakeholder consultations suggest that a significant number of smallholders do not buy irrigation pumping equipment for the following reasons:

- Some farmers use manual, canal, or gravity irrigation, or only plant during the rainy season
- Many rent a pump from their neighbours/family.
- Some pay a cooperative membership, which includes communal use of water pumping equipment.

Although these arrangements may be satisfactory in operations close to subsistence levels, farms entering a higher level of commercialisation are likely to need more reliable irrigation options.

Farmers interviewed in the FGDs expressed frustration at the lack of mechanisms to fund capital equipment. The consensus of key stakeholders interviewed and FGDs provide the following CAPEX estimates:

- Diesel pumps (generic)[36, 37]: T SH 270,000 to 600,000 (US$117- US$261)
- *Lister Petter*[38] diesel water pumps: T SH 800,000 to 3,000,000 ( US$347- US$1,304)
- Mechanical pump: T SH 400,000 (US$174)

Farmers also expressed disappointment at the lack of local maintenance services for their irrigation systems. One stakeholder mentioned that most of the irrigation equipment marketed in Tanzania (e.g. electric motors and pump sets, diesel engines, submersible pumps, sprinkler and drip irrigation systems) are imported—mainly from China, UK, the Netherlands, Italy, Germany, Finland, South Africa and Israel. The off-country location of these manufacturers means that lack of points of service for irrigation equipment can be a problem for farmers.

[35] Note: In the context of this report, 'irrigated area' refers to farmers that actively irrigated with means other than rain. In our sample, 10 farmers (i.e. 2.2% of the sample) used only rain to produce crops (see Section 6.1). In this table, no irrigated areas or TGIN were accounted for this group of farmers.
[36] Mr. Yusuf Seif Mohamed. Interview carried out in 09/07/2018 in Nzega.
[37] Models mentioned in the Stakeholder Report Kilimanjaro, Arusha and Manyara. Kakute, Simusolar and CLASP.
[38] http://www.lister-petter.com

None of the stakeholders or farmers interviewed seemed to know the capital expenditure necessary to acquire a SWP. Additional research provided the following indicative prices:

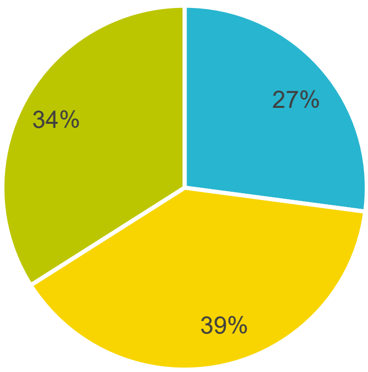
- Futurepump Model SF1 (lifting 2,500 L/hr at 1 m, 1,600 L/hr at 6 m): T SH T SH 1,505,012 (US$650)[39]
- Futurepump Model SF2 (lifting 2,200 L/hr at 1 m, 2,000 L/hr at 6 m): T SH 1,609,206 (US$695)[23]
- SunCulture RainMaker2 Submersible (max. head 70 m and 3,000 L/hr): T SH 2,932,000 (US$1,255)[40, 41]
- Lorentz PS2-4000 C-SJ8-15 (max. head 80 m and 13,000 L/hr):T SH 12,194,000 (US$5,227) [42]

There are less than five SWPs retailers in Tanzania, operating primarily out of Dar el Salam, Mwanza, and Arusha. Mostly, they do not offer financing or packaged solutions; every purchase is in an item-per-item basis.[43] Further, retailers selling SWPs do not offer installation, instead they connect the purchaser with local installers who negotiate separately. Installation and after-market servicing are generally a challenge, as providers are highly fragmented and quality is difficult to evaluate. While some retailers provide a short warranty on products, it does not include transportation and generally requires the client to bring the pump back to the office for evaluation.

## 6.3 Depth of well

Fifty percent of farmers surveyed use a well for irrigation, with 27% of the wells being less than 3 m deep and a similar proportion (34%) which are deeper than 7 m. Technically, boreholes and submersible pumps could be utilized at depths greater than 7 m, although they represent a more significant investment than hand-dug wells. This point is further discussed in Section 7.2.

*Figure 4. Well depth of sample*




| Cluster | Depth (m) |
|---|---|
| Shallow wells | < 3 |
| Mid-depth | 3 - 7 |
| Deep wells | > 7 |

## 6.4 Distance between field and water source

In our sample, 67% of the irrigated fields are less than 100 m away from the main water source. However, regional components must be considered: a report that compared the average distances to water in Morogoro, Tanga, Dodoma, Dar es Salaam and Kilimanjaro found that farmers in Dodoma collected water from sources that were 450 m away from the fields, on average (Keraita and de Fraiture, 2012).

In the present study, the average distance between field and water source for farmers in the Kilimanjaro area was 602 m. In other regions, there were some cases where fields were situated as far as 2 - 3 km away from the closest water source. Popular mechanical pumps such as the Moneymaker model—which have a reach of 200 m—fit the needs of a large segment of farmers. This model, however, would not fulfil the average needs of farmers in Kilimanjaro, according to our sample. This observation may represent an opportunity for SWPs and other types of irrigation pumps.

## 6.5 Total gross irrigation need

This parameter is a key factor for selecting irrigation pumps. Survey data were input into the CropWat software (FAO, 2018), including: crop type; harvests per year and planting schedule; irrigated area; location-dependent

[39] https://www.davisandshirtliff.com/
[40] In Kenya, it is offered in 30 monthly instalments of KSHS 3,900 (US$39) and initial deposit of KSHS 8,900 (US$89).
[41] https://www.facebook.com/SunCultureKenya/
[42] https://www.sustainable.co.za/lorentz-ps2-4000-c-sj8-15-solar-powered-pump.html
[43] There is only one SWP provider offering packaged deals with seasonal and customized financing solutions.

climate variables (including data for the long and short dry/rainy season, as per plating schedule); and soil type (according to agroecological zone, although it is highly variable even within the same farm).[44]

Regarding planting schedules and seasonal changes, the calculation of TGIN was based on the season with the greatest water demand.[45] Planting schedules for several crops often fall between rainy and dry seasons, because the crops need both the rainfall of the wet season and the warm temperatures of the dry season.

This analysis finds that roughly 46% of the sample has irrigation needs of less than 720 L/hr. This demand is well within the SWP capacities of different models, discussed in Section 6.2. The maximum TGIN calculated (22,680 L/hr in Table 3), would need to be serviced through the use of two or more SWPs, depending on the model selected.

### 6.6 Estimation of horticulture income

As previously discussed, data on horticulture income[46] was estimated through secondary sources (Food and Agriculture Organization, 2018d). There are some limitations to this approach: the most recent FAO data is from 2016 and prices are not available for all crop types. Further, there are significant variations in the prices producers are paid. These variations depend on a myriad of factors, including production, demand and supply, supply chain factors (i.e. export or domestic, local or regional), seasonality, and varying consumer preferences. For example, a previous survey noted that the tomato production in Dodoma was about twice as profitable as Morogoro's (Keraita and de Fraiture, 2012). These variations are likely to lead to disagreement between true income in our sample and FAO data. Therefore, the gross income estimates presented here **should be treated as indicatives** only.

Our analysis indicates that 44% of the farms derive a horticulture income of less than T SH 3 million per year (US$1,303). High-income operations (i.e. above T SH 10 million or US$4,342) represent 11% of the sample. The farms surveyed spend on average 3.5% of their horticultural income in capital items for irrigation, annually.

## 7 Irrigation technology uses and adoption patterns

In this Section we analyse the trends of the six key variables selected against the three multi-level factors: irrigation technology, water source and purchase drivers. We finalise the section with some considerations about financing mechanisms.

### 7.1 Irrigation technology

Table 4 presents the average values for the six variables by irrigation technology, from the strongest association[47] (depth of well, $\bar{r}$ =0.63) to the weakest (CAPEX, $\bar{r}$ =0.45). It also shows the percentage adoption of the different pump technologies registered in the survey. The majority of farmers reported using manual means (41%), followed by diesel pumps (36%). The uptake of SWPs in the sample analysed was zero.

[44] The calculation of TGIN does not consider irrigation efficiency factors: it only accounts for the 'bare needs' of water to grow the crops.
[45] The highest irrigation needs are detected as follows: tomato, late season (May to September); cabbage, early season (March to August); other vegetables, late season (April to July).
[46] Derived from sales, without considering expenses, taxes or any other costs.
[47] Average Pearson correlation coefficients across all types of irrigation technologies.

*Table 4. Average values of the six key variables calculated as a function of irrigation technology*[48]

| Irrigation Type | No. farmers using | Uptake relative to total sample (%) | Depth of well (m) | Irrigated area (acres) | Hort. Income (TSH million) | TGIN (L/hr) | Distance to water (m) | CAPEX (T SH) | % CAPEX [49] |
|---|---|---|---|---|---|---|---|---|---|
| Manual | 188 | 41% | 7.0 | 1.5 | 4.2 | 1,924 | 216 | 64,280 | 2% |
| Diesel | 163 | 36% | 16.7 | 2.2 | 6.2 | 2,693 | 307 | 339,270 | 6% |
| Canal | 84 | 18% | 8.8 | 2.5 | 7.1 | 2,488 | 1,091 | 224,417 | 3% |
| Mechanical | 8 | 2% | 7.1 | 1.2 | 3.0 | 688 | 21 | 321,250 | 11% |
| Other | 6 | 1% | 30.0 | 2.0 | 5.2 | 804 | 104 | 100,500 | 2% |
| None | 10 | 2% | NA | 0.2 | 0.5 | 0 | 5 | 87,250 | - |

Other key observations from Table 4 are:

- **The size of the irrigated area and the irrigation technology used are correlated:** Larger irrigation areas are correlated to the use of diesel pumps ($\bar{r}$ =0.78) and canal irrigation ($\bar{r}$ =0.74). Farms with smaller irrigated areas are serviced by mechanical, manual and rainfed systems.
- **Further, the potential of increasing irrigated areas through transition to a better technology is latent.** This potential—defined in this report as the percentage difference between total farm area and irrigated area—is[50]:
    - For users of rainfed systems[51]: 75%
    - For users of manual systems: 62%
    - For mechanical pump systems: 57%
    - For diesel pump systems: 47%
    - For canal irrigation users: 31%
- **Irrigation needs and irrigation technology are correlated**: Higher TGINs are associated to diesel ($\bar{r}$ =0.78) and canal ($\bar{r}$ =0.63) systems, suggesting that both irrigation options are being preferred in larger operations over other types of irrigation.[52]
- **For well users, well depth correlates with the choice of irrigation technology:** Deep wells are correlated with the use of diesel pumps ($\bar{r}$ =0.88), with average depths of 16 m.
- **CAPEX for irrigation correlates with the choice of technology:** Higher levels of CAPEX were detected for diesel ($\bar{r}$ =0.80), and canal ($\bar{r}$ =0.66) systems. Diesel pumps are the second most prevalent system in our sample, which indicates that extra expenditure to acquire better irrigation technology (e.g. SWPs) is not an unsurmountable hurdle for adoption.
- **Horticultural income is associated to the type of irrigation technology used**: Diesel pumps ($\bar{r}$ =0.80) and canal irrigation ($\bar{r}$ =0.73) correlate with the highest horticulture incomes, whereas rainfed crops present the lowest average income. Low income from horticulture can stem from selecting inefficient irrigation systems. Low income can also drive farmers to adopt inefficient, low cost irrigation means. Breaking this cycle will require stronger interventions than simply substituting existing means with other irrigation technologies, such as SWPs.

[48] Figures in highlighted cells represent the largest values per column. Note: some farmers declared using more than one type of irrigation system, e.g. diesel + canal. Therefore, the sum of the number of farmers in this table is different from the total number of farmers surveyed
[49] as a proportion of income
[50] This finding is further discussed in Section 6.1: Irrigated Horticulture Area.
[51] Note that farmers had the option of selecting more than one irrigation system in use; some farmers using rainfed systems declared an area irrigated by means other than rain, thus bringing down the percentage difference from the expected 100% to 75%.
[52] High TGIN levels are also correlated to the irrigation of tomato crops ($\bar{r}$ =0.90); in particular, late-season tomato (planted in early May) has the highest TGIN from the crops cultivated by farmers in our sample. The growth cycle of late-season tomato ends in late September, therefore about three quarters of the growth takes place in the long dry season, which increases the need for irrigation. The analysis of crops and irrigation technology was not included in this report in the sake of brevity.

## 7.2 Water source

Table 5 presents the significant relationships between the source of water and five of the six key variables[53], ordered from the strongest association (CAPEX, $\bar{r}$ =0.34) to the weakest association (distance to water source, $\bar{r}$ =0.33).[54]

*Table 5. Average values of the six key indicators calculated as a function of water source[55]*

| Irrigation Type | No. farmers using the system | % use of the total sample[56] | CAPEX (T SH) | Area irrigated (acres) | Hort. Income (TSH million) | TGIN (L/hr) | Distance to water (m) | % CAPEX [57] |
|---|---|---|---|---|---|---|---|---|
| Surface water (river, stream, lakes) | 283 | 53% | 194,605 | 1.9 | 5.2 | 2,160 | 514 | 4% |
| Hand-dug well | 193 | 36% | 149,237 | 1.9 | 5.4 | 2,520 | 234 | 3% |
| Borehole | 23 | 4 % | 187,196 | 1.7 | 4.7 | 1,440 | 32 | 4% |
| Canal | 19 | 4% | 376,895 | 4.0 | 6.7 | 1,800 | 656 | 6% |
| Rain (no storage) | 8 | 2% | 83,063 | 0.75 | 2.0 | 288 | 20 | 4% |
| Rain (storage) | 6 | 1% | 163,333 | 1.3 | 4.1 | 1,800 | 21 | 4% |

Note: Items in red font represent the largest values per column.

The following observations can be drawn from Table 5 and from additional Pearson correlation analyses performed:

**Surface water bodies are the most common source used for horticultural irrigation:** Over half of the farmers surveyed are using surface water sources, with hand-dug wells being the second most used source (36%). These findings are similar to a previous survey on the subject (Keraita and de Fraiture, 2012).

**Some farmers use more than one water source:** For example, the use of hand-dug wells correlates with the use of surface water sources ($\bar{r}$ =0.59), and the use of boreholes is associated to the use of rain with storage systems ($\bar{r}$ =0.58). The survey did not cover the specific timing of water source uses (i.e. whether farmers use these systems in parallel or seasonally), although the assumption is that surface water sources and rain are used during the wet seasons, while boreholes and wells are used during the dry seasons.

**The water source used is linked to the irrigation technology implemented:** As expected, the use of surface water sources (rivers, streams and lakes) are strongly correlated to canal irrigation users ($\bar{r}$ =0.78). Canals also present the longest distances to irrigated fields, followed by surface water and wells, which indicates that water pumping holds value even for farms with canal access. Farmers using diesel pumps are also drawing water from surface water bodies ($\bar{r}$ =0.62), together with wells ($\bar{r}$ =0.61). Farmers using manual systems (e.g. buckets) primarily use hand-dug wells ($\bar{r}$ =0.73).

**Canal water sources are servicing larger average irrigation areas,** whereas rain (with and without water storage) service smaller areas.

**Horticultural incomes are associated to the type of water source used:** Canal water sources present the highest average income, followed by hand-dug wells and surface water. Rainfed operations with no rain storage systems reported the lowest average income.

**Canal systems presented the highest levels of CAPEX.** The installation costs of diversion intakes with long head canals, and the longer distances between fields and water are likely to lead to higher capital requirements than other options. Surface water, hand-dug wells, and boreholes had similar levels of CAPEX. Regarding the proportion of CAPEX spent as a function of horticulture income (% CAPEX), hand-dug wells presented the lowest values, closely followed by surface water and borehole sources. Canal users present the highest levels of expenditure as a proportion of income.

- **Hand-dug well users had the largest TGIN, closely followed by surface water users.** Given the robust horticulture income associated with these high TGIN groups, hand-dug well and surface water users present a good profile for SWP adoption. However, further understanding of their relatively low reinvestment

[53] Depth of well was left out of the analysis given the obvious correlation between use of well and depth.
[54] Average Pearson correlation coefficients across all types.
[55] Note that one farmer may have declared multiple water sources. Therefore, the total number of farmers in this table is different from the total sample (N=407).
56 1.1% of the sample did not declare a water source.
57 As a proportion of income.

(represented by the % CAPEX as a proportion of income) is required to develop appropriate engagement strategies.

- **There is a relationship between water source and water availability:** Both hand-dug well use ($\bar{r}$ =0.86) and surface water ($\bar{r}$ =0.81) use correlate with water available for irrigation all-year round. Overall, water is readily available for most farmers, except for those using rainfed systems.

## 7.3 Factors of purchase for irrigation technology

In our sample, 56% of farmers across all irrigation types were dissatisfied with their irrigation system. Table 6 shows the level of satisfaction as a function of the adopted irrigation system.

*Table 6. Level of satisfaction with irrigation technology*

| | Canal | Diesel | Manual | Mechanical | Other | None (rainfed) |
|---|---|---|---|---|---|---|
| Does the system fully meet your irrigation capacity and needs? | YES: 39%<br>NO:61% | YES:50%<br>NO: 50% | YES: 41%<br>NO: 59% | YES: 25%<br>NO: 72% | YES: 33%<br>NO: 77% | YES: 20%<br>NO: 80% |

Table 6 shows that the most dissatisfied farmers are those using mechanical and rainfed systems (and those that did not declare a specific type). For diesel pump users, there is an even split between satisfied and dissatisfied customers. Although no specific cause was pointed out in the survey, the generally high dissatisfaction levels could be partly attributed to operational costs (e.g. fuel for motorised pumps), which may open a point of entry for SWPs. Canal irrigation users, who have similar CAPEX levels to diesel pump users, are more dissatisfied with their irrigation system than the latter group.

Building on the results of Table 6, we analysed an open-ended question that goes to the heart of why farmers choose one irrigation technology over others:

- What were the reasons for acquiring this system over other existing irrigation options?

This question—analysed through *Nvivo* to calculate the word frequency of main themes—uncovered 11 common themes, summarised in Table 7.

*Table 7. Main themes mentioned as factors of irrigation technology purchases*

| Theme | Typical statement | Frequency [58] | % respect to total responses |
|---|---|---|---|
| 1. Cost and affordability | "Cheap, affordable"<br>"Not too expensive"<br>"There are no water pumps that are cheaper to operate."<br>"Other technology is expensive" | 192 | 31% |
| 2. Availability of equipment and inputs | "Only type available in my village"<br>"No alternatives"<br>"Best pump available"<br>"Only type of pump available" | 123 | 18% |
| 3. Water source | "My fields are close to canals"<br>"My field is close to the intake, so I use canals to direct water to my fields"<br>"River close to the field" | 80 | 12% |
| 4. Simplicity of use | "Simple to manage"<br>"Difficult to use other system because of distance to water source"<br>"Easier than bucket" | 69 | 10% |
| 5. Lack of awareness of other pump technologies | "I am not aware of other technology available"<br>"I don't know other technologies"<br>"Only system I know" | 44 | 6% |
| 6. Irrigated area (size and location) | "Able to irrigate a large area"<br>"Because the infrastructure of the area supports the technology"<br>"Easier to irrigate large area for short time" | 35 | 6% |
| 7. Reliability/ efficiency | "Reliable"<br>"Performs better than other methods of irrigation, (e.g. buckets and money maker)"<br>"It irrigates better, instead of canals – they lose a lot a water" | 31 | 5% |
| 8. Village dynamics[59] | "Only method used in my village"<br>"Everyone in the village uses this method"<br>"Canal system commonly used in our village"<br>"We have never had any different system" | 29 | 4% |
| 9. Seasonality | "We have the river and canals which are cheap. I use pumps during the dry season"<br>"When canals are full of water, I don't need an option. But when water dries, I use pump" | 21 | 3% |
| 10. Saving labour and time | "Easier to irrigate large area in a short time"<br>"Saves time"<br>"Labour reduction" | 13 | 2.0% |
| 11. Increase production | "Because I need to increase irrigation to get more yield"<br>"Because I want to increase production to become a commercial farmer"<br>"High outputs" | 10 | 2% |

[58] One farmer may have expressed multiple drivers of purchase in more than one way; therefore, the sum of frequencies is higher than the total number of individual farmer surveys.
[59] Refers to the village (community) and peer influence on the choice of system.

Table 8 (pg. 25) shows the top five themes for further investigation, plus one special driver category grouping together farmers who were concerned about two technical characteristics of irrigation technologies (irrigated area and reliability/efficiency). Additionally, to gain an understanding on potential building blocks for a farmer typology based on these purchase drivers, we carried out a correlation analysis to find associations with other variables/factors of importance. Table 9 (pg. 25) assists further in the interpretation of the results.

**1. Cost and affordability**: The concepts of 'cheap' and/or 'affordable' are different. What is affordable for one farmer, may not be so for another. Within this general category, there were also concerns regarding operation costs and lack of capital investment capability, suggesting that 'affordable' equipment could be framed in terms of ensuring that periodic costs or cash outflows are achievable by farmers as a total life-cycle investment. On the other hand, 'cheap' has a straightforward interpretation as 'low cost': farmers in our sample are more focused on the downside of initial investment than the upsides of revenue gain. In other countries (e.g. Kenya), the entry point has been moving farming from small-scale operations to larger sustainable agribusiness (Hartung and Pluschke, 2018). Therefore, the aspect of cost must be addressed with suitable financing options.

**Box 1: Building blocks for the cost-driven farmer**

- Cost and affordability as a driver of purchase was strongly correlated to the use of manual irrigation systems ($\bar{r}$ =0.93) and hand-dug wells as water sources ($\bar{r}$ =0.80).
- Sales channels have also a strong association with cost/affordability ($\bar{r}$ =0.84), with 44% of farmers selling their products at farm gate and 26% selling in local markets.
- Cost and affordability also correlate to the use of peers ($\bar{r}$ =0.80) and marketing groups/cooperatives ($\bar{r}$ =0.70) as the preferred source of market and price information.
- Less than half of these customers are satisfied with their irrigation choice (47%, $\bar{r}$ =0.75).
- On average, the cost-driven farmers sell 77% of their vegetable production ($\bar{r}$ =0.73).
- About two-thirds of these customers have water available all year round (74%, $\bar{r}$ =0.71).
- Farmer orientation also has a strong association to cost/affordability ($\bar{r}$ =0.70), with 40% classified as *commercial farmers* and 38% classified as *loosely market oriented*.
- As a driver of purchase, cost/affordability is in a class of its own: that is, there was no strong correlation to any other driver of purchase.

**2. Availability of equipment and inputs**: This group expressed that their purchase was driven by a lack of other irrigation options, which highlights the importance of stocking SWPs and their relevant spare parts with the preferred suppliers of irrigation equipment in each region/district. Farmers in rural locations often have limited options for inputs and agricultural/irrigation equipment. The lack of SWP uptake identified among the surveyed farmers may be indicative of a lack of well-developed supply chains and stocking with local (regional) distributors. While SWP distributors exist in Dar es-Salam, Arusha and Mwanza, they are few and possibly unknown to farmers making infrequent trips to urban centres. The issue of rural distribution of agro-inputs for horticulture production was discussed often by farmers and stakeholders during the collection of primary data in this study, and it is a well-documented issue in Tanzania (Feed the Future Partnering for Innovation, 2016). Any effective SWP go to market strategy will need to increase the availability closer to the farm.

## Box 2: Building blocks for the distribution-reliant farmer

- In this group, the proportion of farm activities carried out by hired labour is 65% ($\bar{r}$ =0.78), compared to 45% in the cost/affordability group.
- Sixty-four percent of these customers have water available all year round ($\bar{r}$ =0.74).
- In average, the *distribution-reliant farmer* sells 74% of their vegetable production ($\bar{r}$ =0.72).
- In this group, 37% are classified as *commercial farmers* and 27% classified as *market oriented farmers* ($\bar{r}$ =0.73).
- Equipment availability as a driver of purchase was strongly correlated to the use of surface water sources ($\bar{r}$ =0.70) and diesel pumps ($\bar{r}$ =0.67).
- This driver also correlates to the use of downstream market players such as retailers, middlemen and wholesalers ($\bar{r}$ =0.63) as the preferred source of market and price information.
- Sixty percent of the *distribution-reliant farmers* are dissatisfied with their irrigation choice ($\bar{r}$ =0.62).
- Equipment availability has also a strong association to sales channels ($\bar{r}$ =0.62), with 37% of farmers selling at farm gate and 22% selling to wholesalers.
- Equipment availability has an association with: a) the *increase production* driver ($\bar{r}$ =0.68); b) the *water source* driver ($\bar{r}$ =0.63); and c) the *village dynamics* driver ($\bar{r}$ =0.62). This means that farmers that talked about availability also raised these three other drivers.

**3. Water source:** Several farmers spoke about the influence of water availability and sources on their irrigation system choices. For example, some farmers use canal irrigation during the rainy seasons and pumps during the dry seasons to overcome water shortages and competition with other farmers. There are also farmers that exclusively use seasonal rains. Given that 53% of farms depend on surface water bodies, the industry must show how SWPs fit as a solution for these sources (and hand-dug wells, which were the second largest water source used). Water source is undoubtedly a significant factor of selection for irrigation systems.

## Box 3: Building blocks for the water conscious farmer

- Water source as a driver of purchase was strongly correlated to the use of canal irrigation ($\bar{r}$ =0.88) and the use of surface water sources ($\bar{r}$ =0.78).
- This driver also correlates to the use of downstream market players (e.g. retailers, middlemen and wholesalers) as the preferred source of market and price information ($\bar{r}$ =0.82).
- Water source correlates with two other purchase factors: a) *village dynamics*, ($\bar{r}$ =0.80); and b) the desire to *increase production* as a key driver of purchase ($\bar{r}$ =0.80).
- Fifty-eight percent of *water conscious farmers* are dissatisfied with their irrigation choice ($\bar{r}$ =0.74).
- In this group, 48% are classified as *loosely market oriented* and 27% classified as *commercial farmers* ($\bar{r}$ =0.73).
- Sixty-four percent of these customers have water available all year round ($\bar{r}$ =0.71).
- On average, the *water conscious farmer* sells 76% of his/her vegetable production ($\bar{r}$ =0.79).
- Water source and sales channels also an association ($\bar{r}$ =0.61), with 60% of farmers selling at farm gate and 22% to wholesalers.
- Amongst the six typologies, *water conscious farmers* present the highest horticultural income, combined with the largest distances between field and water, and the highest irrigation needs.

**4. Simplicity of use:** Farmers prefer systems that are easy and simple to manage. Some systems such as buckets and the "MoneyMaker" system were mentioned as difficult to implement (possibly due to the high physical effort required to be operated). In contrast, diesel pumps were described as simple and easy to manage. The SWP industry needs to keep in mind simplicity as a key design principle, noting that for most farmers this technology is new. Therefore, training and after-sales attention may be necessary to decrease the knowledge barrier. Regarding design, additional functionality features in SWPs need to be balanced against the significant influence of "ease of use" as a purchase decision factor

### Box 4: Building blocks for the effortless farmer

- Simplicity as a driver of purchase was correlated to the use of mechanical ($\bar{r}$ =0.54) and manual irrigation ($\bar{r}$ =0.46).
- This driver as a driver also correlates with the *technical farmer* typology ($\bar{r}$ =0.51).
- Simplicity also correlates with the driver to match the farm's *irrigated area* ($\bar{r}$ =0.48).
- *Effortless farmers* use government information ($\bar{r}$ =0.46) as their main source of market and price information.
- Sales channels have also an association with simplicity ($\bar{r}$ =0.42), with 44% farmers selling at farm gate and 29% selling at the local market.

**5. Lack of awareness about other pump technologies:** Several farmers indicated that their purchase was based on their current knowledge of the available options/equipment. Some were not aware of better options at the time of purchase. It follows that awareness of SWPs is low in the regions investigated. Lack of promotion of SWPs has been recognized as an issue in past efforts to expand their market in other countries (CEEW, 2018a; Hartung and Pluschke, 2018). Increasing SWP awareness will require time and a consistent marketing effort, geography by geography. Additionally, tangible evidence that this technology can meet farmers' needs is required. 'Word of mouth' promotion through neighbours using SWPs should be considered. At a minimum, demonstrations of SWPs for irrigation purposes need to be undertaken.

### Box 5: Building blocks for *the unaware farmer*

- Lack of awareness on other irrigation alternatives (e.g. SWPs) as a (negative) driver of purchase was correlated to the use of canal, both as a means to irrigate ($\bar{r}$ =0.53) and as a water source ($\bar{r}$ =0.48). Surface bodies as water sources are also correlated to this typology ($\bar{r}$ =0.41).
- This typology correlates with the *village dynamics* ($\bar{r}$ =0.52) driver.
- Unaware farmers have the highest capital expenditure levels, both as a stand-alone measure and as a proportion of the horticultural income.

**6. Technical characteristics:** This group was concerned about matching their irrigation needs (particularly areas and distances to water) and ensuring a reliable and efficient irrigation operation with their selected technology. Some farmers used *efficiency* as a proxy for avoidance or minimization of water wastage. Drip irrigation technology paired with SWPs could address this concern: the water saving qualities of drip irrigation, particularly in water scarce regions where boreholes or wells are used, have been proven in vegetable growing (Feed the Future Partnering for Innovation, 2016). Regarding operation, solar offers a reliable energy source for irrigation, particularly in areas not connected to the grid and where supply of fuel and maintenance services are irregular.

### Box 6: Building blocks for *the technical farmer*

- In this group, the proportion of farm activities carried out by hired labour is 68% ($\bar{r}$ =0.71), compared to 45% in the cost/affordability group.
- Technical features as drivers of purchase were correlated to the use of diesel ($\bar{r}$ =0.69) and hand-dug wells as water sources ($\bar{r}$ =0.53).
- This driver correlates to the use of peers ($\bar{r}$ =0.63) and downstream market players such as retailers, middlemen and wholesalers ($\bar{r}$ =0.63) as the preferred sources of market and price information.
- In this group, 59% are classified as *commercial farmers* and 26% are classified as *loosely market oriented farmers* ($\bar{r}$ =0.60).
- On average, the *technical farmer* sells 81% of their vegetable production ($\bar{r}$ =0.58), the largest share of the six driver groups.
- Sixty-eight percent of these customers have water available all year round ($\bar{r}$ =0.54).
- The technical driver also correlates with other three purchase factors: a) *saving time and labour* ($\bar{r}$ =0.53); b) *simplicity* ($\bar{r}$ =0.51); and c) *increase production* ($\bar{r}$ =0.46).
- Forty-five percent of *technical farmers* are dissatisfied with their irrigation choice ($\bar{r}$ =0.50).
- Sales channels have an association with this driver ($\bar{r}$ =0.47), with 43% of *technical farmers* selling at farm gate and 14% selling to local and district markets, each.
- *Technical farmers* that use wells present the deepest levels from the six types detected, with an average of 22 m (see Table 9).

The use of these typologies is further discussed in Section 9.

*Table 8. Proportion of farmers per type of pump that expressed each factor of purchase*[60]

| Theme | Technology type / pump | | | | |
|---|---|---|---|---|---|
| | Manual/ Cost-driven farmer & Effortless farmer | Mechanical/ Effortless farmer | Diesel/ Technical farmer & distribution-reliant farmer | Canal/ Unaware farmer | Other/ No significant driver |
| Cost and affordability (N=192) | 120 (63%) | 2 (1%) | 31 (16%) | 33 (17%) | 6 (3%) |
| Availability of equipment and inputs (N=123) | 35 (29%) | 4 (3%) | 55 (45%) | 23 (19%) | 6 (5%) |
| Water source (N=80) | 18 (23%) | 0 (0%) | 25 (31%) | 24 (30%) | 5 (6%) |
| Simplicity of use (N=69) | 30 (44%) | 2 (3%) | 25 (36%) | 9 (13%) | 2 (3%) |
| Lack of awareness about other pump technologies (N=44) | 10 (23%) | 1 (2%) | 14 (32%) | 15 (34%) | 4 (9%) |
| Irrigated area (N=35) | 10 (29%) | 0 (0%) | 19 (54%) | 3 (9%) | 3 (9%) |
| Reliability/efficiency (N=31) | 6 (19%) | 0 (0%) | 17 (55%) | 5 (16%) | 3 (10%) |
| Village dynamics (N=29) | 12 (41%) | 1 (3%) | 8 (28%) | 7 (24%) | 1 (3%) |
| Seasonality (N=21) | 3 (14%) | 0 (0%) | 8 (38%) | 3 (14%) | 0 (0%) |
| Saving labour and time (N=13) | 3 (23%) | 0 (0%) | 9 (69%) | 0 (0%) | 1 (8%) |
| Increase production (N=10) | 1 (10%) | 1 (10%) | 8 (80%) | 0 (0%) | 0 (0%) |

Table 9 presents the average values for the six variables per irrigation type, from the strongest association (depth of well, $\bar{r}$ =0.65)[61] to the weakest (CAPEX, $\bar{r}$ =0.45). It also shows the percentage adoption of the different typologies previously built.

*Table 9. Average values of six key indicators calculated as a function of farmer typology*[62]

| Farmer typology | Number of farmers[63] | % relative to the total sample | Depth of well (m) | Area irrigated (acres) | Hort. Income (T SH million) | CAPEX (T SH) | Distance to water (m) | TGIN (L/hr) | % CAPEX[64] |
|---|---|---|---|---|---|---|---|---|---|
| Cost-driven farmer | 171 | 31% | 7.7 | 0.7 | 4.7 | 72,920 | 272 | 2,216 | 2% |
| Distribution reliant farmer | 102 | 19% | 9.3 | 0.8 | 5.3 | 292,696 | 463 | 1,961 | 6% |
| Water conscious farmer | 67 | 12% | 8.6 | 1.0 | 6.9 | 137,104 | 811 | 3,026 | 2% |
| Effortless farmer | 55 | 10% | 13.4 | 0.7 | 5.0 | 182,187 | 157 | 2,453 | 4% |
| Unaware farmer | 34 | 6% | 7.4 | 0.9 | 6.1 | 379,912 | 464 | 1,870 | 6% |
| Technical farmer | 56 | 10% | 21.6 | 0.9 | 6.7 | 282,438 | 472 | 2,665 | 4% |
| Other drivers | 63 | 12% | 10.9 | 0.7 | 5.0 | 175,688 | 378 | 2,166 | 4% |

## 7.4 Considerations about financing mechanisms

In agreement with cost/affordability being the top purchase decision factor detected, the stakeholder interviews in Kilimanjaro and Arusha also indicated that affordability is the critical barrier for adoption and operation of new

[60] Highlighted cells denote the largest values per column. Note: one farmer may adopt two or more irrigation systems.
[61] Average Pearson correlation coefficients across all types.
[62] See 67
[63] Farmer typology is not mutually exclusive. Some farmers fall into more than one typology,
[64] As a proportion of income.

irrigation technology. The stakeholders' view is that practical financing models are crucial to drive scaled adoption of SWP technology.

In Tanzania there are financial institutions available for farmer loans; however, there are also barriers to credit access that can be traced back to the farmers' characteristics, the capacity of financial institutions and macro-environment factors. The stakeholders from Dodoma, Tabora and Singida consistently indicated that there are no commercial sources of financing for irrigation equipment (or any other farm expenditure) readily accessible by farmers.

Lack of land ownership is one of the major hurdles for smallholders, as they are unable to use it as collateral for bank loans. In our survey, 50% of farmers have rented land for agricultural activities at some point. Given the high percentage of vegetable farming operations based on rental of land, it is not surprising that farmers find it difficult to access institutional credits and prefer to purchase irrigation systems in cash—favouring loans by private individuals, family, friends and relatives to institutional financing. Other sources of funding detected in our sample were NGOs and capability building projects.

The scarcity of financing mechanisms to support horticulture was also a topic often mentioned in the FGDs. Some farmers mentioned that there are supply chain players (e.g. inputs suppliers, wholesalers) that can provide credit and loans, which are paid back after harvest at unfavourable terms for the farmers. The latter refers to the loan provider setting the price of sale for the crops.

These issues are not unique to Tanzania. Market development efforts for SWPs in other countries have encountered similar problems. For example, in 2015 the Equity Bank Kenya—which had a specific solar pump loan product for smallholders—rejected 200 applications for SWP purchases because of perceived high credit risk (Holthaus *et al.*, 2017). In India, farmers that were lucky enough to obtain a loan from banks found it difficult to implement them due to complicated processes and poor management by bank officials (CEEW, 2018a).

Further, implementing subsidies or similar financing mechanisms does not ensure immediate and lasting positive outcomes. Subsidies ranging from 60% to 100% have expanded India's solar irrigation market, though adoption of SWPs not kept pace with the initial goals the Government of India set when the scheme launched in 2014 (CEEW, 2018b). It is therefore imperative to fully understand how the driving purchase factors that impact decisions about irrigation options can be used to increase adoption of SWPs.

# 8 Market potential for irrigation technologies

The global solar irrigation pump market is predicted to reach 0.9 million units by 2022 (Grand View Research, 2016).[65] China and India represent the largest markets. About two-thirds of the current SWPs installed in India were adopted by farmers switching from electrical/ diesel pumps, while one third of farmers did not use any motorized pump for irrigation prior to their SWP purchase (Hystra, 2017).

Little information is available for markets like Tanzania, where very few measures to promote the development of the SWP market beyond the elimination of VAT and duties for some solar components have been implemented. Hence, there is a need to develop local market intelligence to fill information gaps, such as the market potential for SWPs.

In this study, we applied a top-down segmentation approach, first by defining and sizing the general irrigation technology[66] market in Tanzania, and later applying segmentation approaches. We based our initial market potential estimate on FAO historical country production and yield and price data for the mix of vegetables grown by the farmers in our sample. The gross income from horticulture was multiplied by the average CAPEX-to-income percentage per crop, previously calculated in the data exploration phase. Finally, we fit the historical results to a linear model to forecast the period 2016–2022. Table 10 shows the resulting potential capital expenditure for **all types** of irrigation equipment.

*Table 10. Tanzania's estimated market size for all types of irrigation systems per type of crop.*

| Crop | 2019 | 2022 | CAGR |
|---|---|---|---|
| Beans, green | 201,975 | 355,246 | 12% |
| Cabbages and other brassicas | 1,248,711 | 2,259,917 | 13% |
| Chillies and peppers, green | 599,886 | 1,066,661 | 12% |
| Onions, dry | 6,676,773 | 13,032,145 | 14% |

[65] The global market of solar water pumps is 1.5 million units by 2022, of which 60% is represented by irrigation pumps and the rest being for domestic and potable water uses.
[66] Throughout this report, "irrigation technology" and "irrigation system" are used to denote the range of options available to power water lifting and transport, be human, mechanical or other. We exclude piping, valves, drip tape and other elements that would configure a complete irrigation system.

| | | | |
|---|---|---|---|
| Peas, green | 372,940 | 713,076 | 14% |
| Potatoes | 565,099 | 1,217,806 | 17% |
| Sweet potatoes | 1,380,767 | 2,282,670 | 11% |
| Tomatoes | 5,317,057 | 8,625,117 | 10% |
| Vegetables, leguminous | 298,169 | 582,720 | 15% |
| Vegetables, fresh (otherwise not classified above) | 69,569,964 | 121,172,043 | 12% |
| **TOTAL MARKET** | **86,231,342** | **151,307,401** | **12%** |

Note: Forecasted for 2018 and 2022 (in USD)

This estimate assumes that all Tanzanian horticulture growers adopt some sort of irrigation technology. In our sample, only 0.5% of the farmer population worked exclusively with rainfed crops, indicating that our assumption is valid for this sector.

The SWP industry can theoretically target whole irrigation market, gaining customers by convincing them in that switching to SWPs offers advantages over their current choices. However, through the lenses of different types of segmentation approaches, the market picture looks different.

# 9 Market segmentation

In Section 4.4.3 we outlined the rationale for testing two different *a-priori* segmentation approaches: by market orientation, and by current irrigation technology. Both approaches make sense. Sixty-four percent of stakeholders interviewed recommended marker orientation as a key factor in segmentation, whilst 23% viewed farm area as a key factor. Further, market orientation has been traditionally used as a segmentation concept for farm inputs and technologies (Pienaar, 2013; The Southern Africa Food Lab (SAFL), 2016). A previous report presented a market oriented segmentation approach to recommend financing mechanisms for irrigation technology (2030 Water Resources Group, 2016).

Appendix 4 presents the results of these two segmentation approaches.

## 9.1 Segmentation by market orientation

When segmented by market orientation, our results show a high level of uniformity between subsistence farmers, farmers with a loose market orientation, farmers that are market oriented and farmers that are fully commercial. This homogeneity is likely due to the selection of the farmer sample. The market orientation segmentation indicates that the commercial and loosely market-oriented farmer groups are the most likely candidates to switch to SWPs, due to their higher revenue bracket, high levels of dissatisfaction with their current irrigation technology, and frequent use of diesel pumps, which links to the segmentation by irrigation technology.

The combined value of the commercial and market-oriented segments is US$59.8 million in 2018. We forecast the market to grow to US$104.9 million by 2022. Appendix 4 provides more details on this segmentation approach.

## 9.2 Segmentation by irrigation technology

Previous experiences in the deployment of solar irrigation in India—where the farmers most prone to switch to SWPs were electric and diesel pump users (CEEW, 2018b)—suggests that current irrigation technology is a factor that can accelerate or impede adoption of SWPs. In our study, there are two main distinct groups: diesel pump and canal irrigators, and manual, mechanical and seasonal (rain) irrigators.

In the first group, canal irrigation and diesel pumps combine the largest irrigation areas, the highest irrigation needs, the highest estimated horticultural incomes and similar levels of capital expenditure in the sample surveyed. A plausible explanation is that 13% of farmers that use canal irrigation during the wet seasons also use diesel pump irrigation during the dry seasons. This strategy enables them to 'hedge their bets', extending water availability during the year and obtaining higher annual production. These irrigators present a good profile for SWP adoption.

Farms using mechanical, manual and rainfed systems present significantly lower incomes and lower capital expenditure than the former group. However, manual and rain irrigators also have the largest potential to increase their irrigated areas. Manual irrigators also represent the largest group in our sample and at national level, and therefore represent the largest market 'segment'. This group, although more challenging than the canal irrigators and diesel pump users, also presents opportunities for expansion of SWPs.

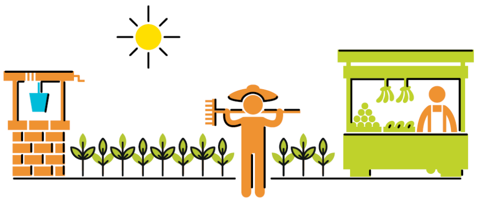
The combined value of the canal irrigation and diesel pump segments is US$46.4 million in 2018 and forecasted to grow to US$81.4 million by 2022. Appendix 4 provides more details on this segmentation approach.

### 9.3 Segmentation by purchase factors

The two *a-priori* segmentation approaches above are the methods that are normally applied to agricultural equipment and may be useful as such for some stakeholders. However, our view is that purchase factors are more precise indicators than market orientation or irrigation technology.

We therefore turned to the drivers of purchase and the typologies developed in Section 7.3. We provide a summary of the characteristic for each farmer type next.

## THE COST-DRIVEN FARMER



- Uses manual irrigation methods because they are cheap or affordable
- Largest market share (31%) and lowest irrigated area (0.7 acres) and reinvestment (1.6 cents per US $ earned)
- Sources market and price information from other farmers and marketing groups/cooperatives

## THE DISTRIBUTION-RELIANT FARMER

- Uses diesel pumps because they are the available technology in his/her location
- Market-oriented approach to information sourcing and sales (37% commercial farmers, 22% sell to wholesalers)
- Moderately low irrigation needs (1,961 L/hour)

### The cost-driven farmer

**Market Value**

**31%**
of total

**US $26.7m**
in 2018

**US $46.9m**
in 2022

**Finances**

**US $2,044**
average annual income from horticulture

**US $32**
average annual capital expenditure

### The distribution-reliant farmer

**Market Value**

**19%**
of total

**US $16.4m**
in 2018

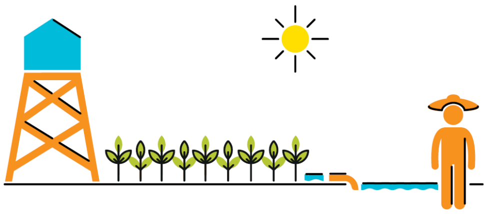
**US $28.7m**
in 2022

**Finances**

**US $2,305**
average annual income from horticulture

**US $127**
average annual capital expenditure

## THE WATER-CONSCIOUS FARMER



- Uses canal irrigation due to availability of surface water sources
- Highest horticultural income
- Largest distance between field and water source (811 m), highest irrigation needs (3,026 L/hour), and highest irrigation area (1 acre)

### Market Value

**12%**
of total

**US $10.4m**
in 2018

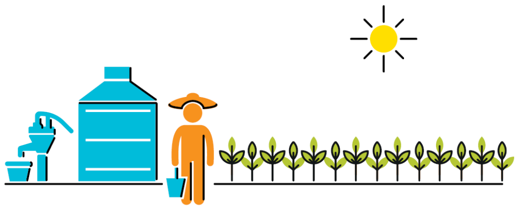
**US $18.2m**
in 2022

### Finances

**US $3,000**
average annual income from horticulture

**US $60**
average annual capital expenditure

## THE EFFORTLESS FARMER



- Uses mechanical and manual irrigation because of their close proximity to water sources (157 m average) and the simplicity of irrigation choice
- Lowest satisfaction with irrigation technology (31%)
- Turn to government for information about market dynamics

### Market Value

**10%**
of total

**US $8.6m**
in 2018

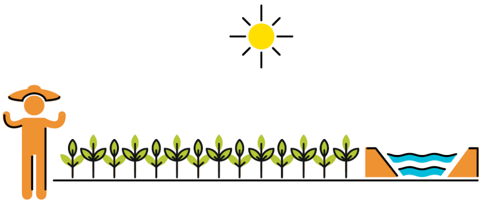
**US $15.1m**
in 2022

### Finances

**US $2,174**
average annual income from horticulture

**US $79**
average annual capital expenditure

## THE UNAWARE FARMER



- Uses canal irrigation because methods are familiar, though village dynamics may also be an influencing force
- Lowest irrigation needs (1,870 L/hr)
- Highest reinvestment per dollar earned (US $0.06 cents)

### Market Value

**6%**
of total

**US $5.2m**
in 2018

**US $9.1m**
in 2022

### Finances

**US $2,652**
average annual income from horticulture

**US $165**
average annual capital expenditure

## THE TECHNICAL FARMER

- Uses diesel pumps. Most satisfied with their irrigation choices (55% satisfied)
- Sell 81% of what is produced on the farm
- 68% of all farm activities carried out by hired labor

### Market Value

**10%**
of total

**US $8.6m**
in 2018

**US $15.1m**
in 2022

### Finances

**US $2,913**
average annual income from horticulture

**US $123**
average annual capital expenditure

Regarding typologies by driver of purchase, there is a 7th aggregated group which represents 12% of the sample, represents a current value of US$10.4 million and encompasses a mix of drivers – including village dynamics, seasonality, savings in labour/time and increase in production. Separately, these groups would be too small to justify a segment. Further, we have previously discussed the relevant cross-correlations of most of these drivers with the other – more significant – factors of purchase (i.e. the top six list in Section 7.3). If the key points of the six larger groups are attended, most of the drivers in this 7th group will be covered.

Although there are similarities between some of the farmer types (similarly to the two *a-priori* segmentation approaches), the narrative of the six groups shows the multi-faceted nature of the irrigation market. Most importantly, this approach links the geophysical factors in our sample (i.e. irrigation characteristics) with the human dimension (i.e. purchase drivers). This link is important to understand the frame of mind that potential SWPs customers have when they make a purchase decision and choose a particular irrigation solution over others.

**Box 7: Potential market for surface and submersible pumps**

The use of submersible and surface water pumps is another segmentation consideration, necessary to deliver equipment that matches farmers' needs. In Table 5 (Section 7.2), we established that about 53% of the farmers surveyed use surface water sources, and 36% use hand-dug wells. Only 4% use boreholes, which would call for submersible pumps. However, 27% of well users indicate depths exceeding 7 m, which places these wells as potential candidates for submersible pumps.

Using the considerations above, the **potential market for surface pumps** (including farms drawing from surface water and shallow hand-dug wells) **is estimated at US$69.3 million in 2018 and expected to grow to US$121.5 million by 2022** (if the current trends in the use of surface water continue). The **potential market for submersible pumps (including borehole users and deep wells) is estimated at US$12.1 million in 2018 and expected to grow to US$21.2 million by 2022***.

We previously discussed that farmers using canals as main water sources may also find value in using water pumps when canals are far away from their fields. Canal users represented 3.5% of our sample. An uptake of water pumps from a percentage of this population would lead to a small increase in the market share of surface pumps. The same applies if some rain storage users (which represented 1.5% of our sample) decided to use pumps to move water from storage tanks to their fields.

*Note: these calculations assume a 100% uptake of water pumps (either surface or submersible) by all surface, borehole and well users; the current situation is that 38% of farmers using surface water and 44% using wells as main water sources also use diesel pumps.

# 10 Market Strategy

All the segmentation approaches carried out indicate that the horticulture farmer sample in this study is relatively homogeneous. These results and the relatively small market size for irrigation suggests that horticulture is a segment on itself and may not require further dissection to determine market strategies for adoption of SWP. From a point of view of economies of scale, servicing a homogenous farming group is less expensive than splitting the design and marketing efforts into two or more segments within an already limited market (i.e. horticultural production).

If the SWP industry follows an undifferentiated market strategy, for smallholder horticulture farmers, the industry can still use the customer knowledge generated by the three segmentation approaches hereby produced, concentrating their efforts in horticulture as a (currently) niche agricultural market. This effort can help the industry to gain traction and recognition in a relatively well typified and contained agricultural segment. Further research taking a perspective of farmer personality, values, opinions, attitudes, interests, and lifestyles, may yield more demarcated results.

Through tackling the horticultural market with all the complexities of customers and regions, the industry can increase visibility, establish a robust SWP supply chain, test financing concepts, and gain know-how and resources to eventually expand into other larger agricultural sectors (e.g. grains, dairy, aquaculture). At the rate the horticulture sector is growing, this strategy could also ensure a faster SWP adoption rate than under conditions of divided efforts to service many segments of low value.

It is recommended that the SWP industry focuses on the following suggested actions:

- Design ***products and marketing activities that appeal to the largest number of horticulture farmers***, focusing initially on the farmer types based on purchase factors and developed in Section 7.3. These farmer types also cover different types of irrigation technologies and farmer orientation, which are further detailed in Appendix 4. If there is a need to drill down into the characteristics of one group (without the influence of purchase drivers), Figures A4.1. and A.4.2. can assist.
- In using the typology based on factors of purchase, we need to remember that ***cost/affordability was the top purchase decision detected in this study***. It is recommended to a) carry out market research to detect the purchase price point (particularly for current users of diesel pumps, canal irrigation and manual systems); b) carry out a detailed analysis of operational expenditure associated to these systems as compared to SWPs; and c) design credit/financing mechanisms that bring the annual payments of SWPs in line with the levels of annual CAPEX and operating expense for competing technology.
- ***Availability of equipment and inputs*** was the second most important purchase factor. The distribution of SWPs must reach farmers near their communities and provide or link to spare parts suppliers.
- ***Simple, easy to use equipment*** was also a significant purchase decision driver. To address this aspect, appropriate design by manufacturers and packaging by distributors is essential. Furthermore, *training of farmers and their suppliers will be important*. Lastly, the SWP value chain requires companies with *on-the-ground staff* to attend technical and marketing queries.
- Awareness of solar pump technology is extremely low and uptake of SWPs is non-existent in the sample of farms investigated. A significant ***marketing effort*** will need to be launched to educate potential buyers to prepare the territory for sales. This ***awareness campaign*** should be extended to the preferred local/regional suppliers and spare parts stockists.
- The ***value proposition*** recommended for the horticulture sector could be based on the following elements: affordable irrigation solution with accessible financing mechanisms, minimum operational costs, an extended sales & service network, training, simple operation, and equal or better reliability and irrigation performance that competing technologies.
- The addition of ***complementary products*** such as drip irrigation equipment should be considered, to offer differentiation from fuel-based solutions and to place SWPs within a system that will enhance the performance of the irrigation system as a whole. This strategy has been shown to work in other regions (e.g. India, South East Asia) (Hystra, 2017; CEEW, 2018a; Hartung and Pluschke, 2018).
- Notwithstanding the development of a single concentrated market strategy, the **most** receptive points of entry for SWPs were detected in the following groups:
- **According to Purchase Drivers**: The *technical farmer & the distribution-reliant farmer* (2018 combined market size: US$25 million), which overlaps with the diesel pump switchers in *c* below and the three main categories of farmer market orientation.
- **According to Farmer Market Orientation**: *Commercial farmer & market oriented farmer* (2018 combined market size: US$59.8 million).
- **According to Irrigation Technology**: *Diesel pump users* & *canal irrigation users* (2018 combined market size: US$46.4 million). For farmers using both (i.e. canals for rainy seasons and pumps for dry seasons), the point of entry is the substitution of diesel pumps by SWPs, initially as a seasonal option and eventually as the all-seasons option.

# 11 Conclusions

This research frames the horticulture market in Tanzania, and its current practices, with the intent of understanding potential SWP adoption. Given that no SWP users were identified in our farmer sample, there will be a need for future research, as the market grows and actual field experience can be evaluated.

The lack of SWP use at present indicates that the industry is in its pioneer phase. A multi-faceted, consistent effort will be necessary to develop elements of the market, especially for farmers who are new to irrigation. For substitution-type users, the adoption is expected to be swifter, driven by the relative value.

The different segmentation approaches carried out indicate that the horticultural sector (as represented by our farmer sample) is fairly homogeneous in terms of the irrigation characteristics, market orientation and financial indicators used in this study. Having said this, the report provides some deep customer insights – based on the analysis of the drivers of purchase, farmer orientation and irrigation technologies – that will help the industry to identify receptive groups (e.g. *technical farmers*, diesel pump users) and points of entry for the more difficult (but highly important) *cost-driven* customers, mostly represented by manual irrigators.

Future market research for SWPs should be performed in other agricultural sectors, as it is likely that horticultural applications – which in the larger agricultural market can effectively be treated as a single-segment – will differ from use cases in grain production, livestock, dairy and others. Indeed, each agricultural sector may be a segment on itself.

There are a number of actions that can be taken to catalyse the SWP market, driven directly from this study:

- **Awareness:** development of permanent demo sites, programs and awareness campaigns
- **Knowledge and capacity building:** training, train-the-trainer, ongoing support.
- **Consumer credit:** farmer-friendly financing is central to affordability and perception of cost.
- **Simplicity of design:** ease of installing and managing the irrigation system.
- **Packaged irrigation solutions:** water access with water application such as drip-lines and sprinklers.
- **Accessibility or availability of solution:** well-developed supply chains for SWP equipment, possibly including a network of distributors of equipment and spares when possible.
- **Agronomic support:** input supply and advice, agronomic capacity, and market access support.

Given that there is no common industry association or umbrella organization that can undertake overarching activities on behalf of the SWP industry, it is up to the individual companies to determine their own level of preparedness to tackle one or more of these activities, and the time horizon to achieve these. However, we have some recommendations:

**A key intervention required to promote adoption is increased awareness of SWPs (a).** Farmer engagement, demonstrations, workshops, media, and promotion of existing users in the community are all necessary. While some events can be done remotely, the majority require on-the-field, hands-on interactions with farmers. The new technologies have to be seen in action to convey their value. This promotion and/or education can be implemented by diverse kinds of organizations, but it should always be carried out in collaboration with an entity that would provide access.

In the individual surveys, **farmers conveyed their thirst for knowledge and support (b).** Proven agricultural strategies like training-the-trainer and establishing community champions are an excellent starting point and merit support from NGO's, public bodies, and companies alike.

**Many of the above solutions will not gain traction without credit (c).** These markets are capital starved, with limited land title and financial services that are not well designed for asset acquisition. Given the inherent risks in agriculture, a prudent approach would be to borrow from both agricultural finance (specifically seasonal cash flow features) and microfinance with longer loan terms (Peck and Pierce, 2005). Research on lower income individual needs have similarly underscored that cash flow smoothing and flexibility are more valuable than credit, *per se*.[67] Whether provided by financial institutions or non-financial entities, there is ample and influential work to be done here.

**For designers of equipment, the key recommendation is to focus on ease of use over additional functionality (d).** This guidance could manifest in clear feedback mechanisms, so that farmers can see how the equipment is operating, intuitive and limited controls, and simple servicing options (with limited to no servicing required).

[67] An example is Portfolios of the Poor, http://www.portfoliosofthepoor.com/

**Regarding packaged irrigation solutions (e),** there may be opportunities for collaboration with borehole drillers to provide water access in areas where scarcity is present. The low prevalence of boreholes in the survey is indicative of both the absolute cost and expected cost (given that drilling incurs costs but does not guarantee success). These investments can be justified economically but will likely be pursued by operations that can withstand the risk (e.g. commercially and market-oriented farmers). A related opportunity is for SWP providers to include application of water as part of the solution**.** We highlighted the fact that this strategy has worked in other countries. SunCulture[68] and ennos[69] have piloted this solution in Tanzania and elsewhere with some success. Collaboration between distributors of SWP and sellers of drip or sprinkler irrigation may allow a scaled approach with each party maintaining expertise in their technology.

**Regarding access (f)** – and also related to (b) – the supply of water pumps for irrigation requires understanding of the farm, water source, use case, and farming practices of the buyer. While some farmers may have the sophistication and comfort to purchase a well in an urban centre and carry out installation on their own, the vast majority seek and need support. Developing the market will require a network or distribution scheme that can cost-effectively provide this kind of service. Some successful tools at this stage could include *Results Based Financing* to support pioneer distributors, *programs to train* more pump and well servicers that can provide distributed support as independent or affiliated businesses, *initiatives to aggregate farmers* so that concentrated and/or sizeable groups can be reached cost effectively.

**Added services such as agronomic support (g) are not specific to SWPs.** However, given that a farmer's success does not depend on water alone, the knowledge gap in agronomy cannot be ignored. In the long term, it will be critical that agriculture maintains a progression towards more water efficient practices and consideration of irrigation, not simply in terms of water access but also in water use.

[68] http://sunculture.com/
[69] https://www.ennos.ch/

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# APPENDICES

## Appendix 1. Surveys and questionnaires

Key Informant (Stakeholder) Questionnaire

Key Informants are: government officials, horticultural produce buyers, input suppliers, horticultural support projects, pump suppliers and so on.

- INFORMED CONSENT STATEMENT

This discussion is part of market study, conducted by the Simusolar Ltd based in Mwanza, Tanzania and CLASP, an NGO with headquarters in the Washington DC. The survey is aimed at understanding the market segmentation for irrigation systems, and the size of the market for solar water pumps. The surveys will take place in the Northern Highlands, Central regions (Tabora, Singida and Dodoma) and Morogoro Regions of Tanzania. Simusolar is an off-grid solutions company and CLASP is an NGO committed to driving adoption sustainable energy technologies globally. Your participation in discussing these questions is very much appreciated.

Your responses will be kept **CONFIDENTIAL**. There are no correct or incorrect responses. Please try to answer sincerely; only honest responses are useful to our research. You can ask for clarifications and questions at any given time in the interview. Your responses will enable us the dynamics of the regional horticultural market, the segments of farmers and calculate the size of market available to adopt solar powered irrigation innovations.

Survey objectives

This questionnaire should serve as semi-structured interview guide in obtaining information relevant to horticultural production and market in the region. Key informants possess information on the support infrastructure available to farmers such as finance and credit facilities, input subsidy schemes and market information provisioning. Key Informants also have an insight into the cropping systems and management practices used locally to produce horticultural and high value crops. This information is to be used in open discussion format between the interviewer and the Key Informant (KI). At the end of the discussion, the interviewer should have a clear idea of regional policies, institutions and projects working to develop the horticultural sector and regional commercial agriculture in general.

Every Key Informant is different and will have his/her field of specialization, i.e. extension, irrigation, marketing, government support, credit infrastructure, etc. The interviewer should focus on questions below that can extract the most relevant contributions from KIs.

Questions:

1. What is the background and importance of horticulture in this region/district?
2. How has horticulture developed in the past 5 - 10 years?
3. What are the different channels through which farmers market their horticultural produce?
4. Can farmers in this region/district be segmented into typologies based on:
    a. Access to land and production capital
    b. Type of crops cultivated (cash crops, food crops, horticultural crops)
    c. Demographic classifiers (e.g. age and education level)
    d. Districts and Wards
    e. Proximity to urban areas/major market
    f. Use of external inputs and production technologies, in other words, their level of intensification

*KI should only highlight the factors that he/she thinks are relevant in the research area. The list is non-exhaustive.

5. Describe the unique characteristics of the different farmer typologies?
6. What projects in this area have focused on horticultural technology improvement and adoption in the past 5 years?
    a. Have there been irrigation projects targeting horticulture or other agricultural sub-sectors? E.g. dams for large scale rice cultivation and downstream canals.
7. What (approximation) proportion of farmers in this area are using irrigation? Estimate by:

a. Manual systems: buckets watering cans
b. Mechanical systems: treadle pumps, hip pumps, etc.
c. Diesel/petrol pumps
d. Solar powered pumps
e. Others (kindly specify)

8. What are the costs of the irrigation systems currently sold on the market in this region/district?
9. How do smallholder access and pay for pumps in this region/district?
    a. Are there existing mechanisms such as PAYG?
    b. What organizations/companies are offering financing schemes currently in this area?
    c. How do the existing mechanisms encourage/hinder farmers from purchasing irrigation pumps?
10. What is your view on the potential for future adoption and increase of irrigation technologies in general?
    a. How do you assess the potential market and adoption of solar irrigation systems specifically?
    b. What other irrigation technologies do you envision have a promising adoption potential and market?
11. Considering all production capital (land, finance, inputs, water, etc) for horticulture, what is the estimated percentage increase in horticultural produce that this area can realise with better access to irrigation technologies?
12. What are the broad regional/district level impacts of horticultural production and marketing?
    a. How will these impacts/outcomes be boosted by an increase in irrigation?
13. What are the water sources in the region/district used to irrigate horticultural crops?
    a. How reliable are the available water sources?
    b. How does use of water for irrigation impact water availability for other uses? E.g. livestock, coffee production/processing, potable water, etc?
14. What are some pre-conditions and infrastructural investments needed to improve the chances of accelerating (solar) irrigation uptake?
15. What type of approach(-es) do you advice for companies seeking to develop and market solar irrigation technologies in this region/district?
    a. What support systems and value chain infrastructure do companies need to introduce together with irrigation pumps?
    b. Are there existing companies, organisations and other stakeholders to consider working with?

Individual farmer questionnaire

Narrative

This questionnaire forms part of the research tool applied in a market study, conducted by Simusolar Ltd based in Mwanza, Tanzania and CLASP, an NGO with headquarters in the Washington DC. The questions are meant to better understand market segmentation for irrigation systems, and the size of the market for solar water pumps this region. The surveys will take place in the Northern Highlands, Central regions (Tabora, Singida and Dodoma) and Morogoro Regions of Tanzania. Simusolar is an off-grid solutions company and CLASP is an NGO committed to accelerating the adoption of sustainable energy technologies globally. Your participation in discussing these questions is very much appreciated.

We appreciate your contribution as horticultural farmer or group of farmers as your responses will contribute to Simusolar and its partners being able to develop technologies and provide services that enhance productivity, market integration and increased incomes from horticultural activities.

PERSONAL DETAILS

| | | | |
|---|---|---|---|
| Farmer code: | | MRKIWI1 | |
| Name of farmer: | | *Tel contact (optional): | |
| Village: | Ward: | District: | Region |
| Cooperative member? YES ☐ NO ☐ | | Name of Cooperative: | |
| Do you consider yourself a: | | Subsistent farmer ☐<br>Loose market oriented ☐<br>Primarily market oriented ☐<br>Commercial farmer ☐ | |
| Gender of Household Head: | | Age of Household Head: | |
| Total number of household members: | | How far are your horticultural field from you house?: …………(time to walk to fields) | |
| Adults in your Household:<br>Adults are HH member >15 years | | Highest education level of farmer/HH Head: | |
| What is your total farm size? ……….acres | | Total number of fields: | |
| Do you hire labour for farm activities? | | YES ☐ NO ☐ | |
| If yes, how much of your cropping activities use hired labour? | | ○ Less than 10%<br>○ Between 20 – 30%<br>○ About half, 50%<br>○ More than 50%<br>○ All, 100% | |
| Do you engage in off-farm income activities? | | YES ☐ NO ☐<br>If yes specify…………………………. | |
| What is the major household transport asset? *List main one (1)* | | | |

Section I. MARKETS AND MARKET INTEGRATION

| | | |
|---|---|---|
| 1 | What proportion of your total produce do you sell? | ○ Less of 10%<br>○ Between 20 – 30 %<br>○ Half, 50%<br>○ Up to 75%<br>○ All, 100% |
| 2 | Does this proportion of your sales differ between low and peak season (wet and dry season)? | YES ☐ NO ☐ |
| 3 | Do you sell more or less in the dry or wet season or same throughout the year? | |
| 4 | What are the different markets where you sell your produce?<br>E.g. farm gate, village market, district market, urban market, specialized buyers, pre-agreed contract, export, etc. | 1. ______________<br>2. ______________<br>3. ______________<br>4. ______________ |
| 5 | How do you transport your produce to market? | 1. ______________<br>2. ______________<br>3. ______________<br>4. ______________ |
| 6 | How do you access market information and prices?<br>Select all that apply | ○ Colleagues<br>○ My cooperative group<br>○ Market people (retailers, wholesalers)<br>○ Media (radio, tv, print, app, internet)<br>○ Extension services/agents<br>○ Input suppliers<br>○ Govt/NGO program<br>○ Others (specify).................. |
| 7 | List major challenges you face in marketing your produce.<br>List in decreasing order of importance. | 1. ______________<br>2. ______________<br>3. ______________<br>4. ______________ |
| 8 | How do you get access to horticultural inputs?<br>List all that apply | 1. ______________<br>2. ______________<br>3. ______________ |
| 9 | What is your main challenge in acquiring inputs for cropping? | |
| 10 | Are there existing govt/NGO programs on improving your market and input access?<br>If yes list them and state if they still active... | YES ☐ NO ☐<br>1. ______________<br>2. ______________<br>3. ______________ |
| 11 | In your opinion, how have these initiatives impacted your horticultural productivity and income? | |

| | | |
|---|---|---|
| 12 | What technologies, inputs or knowledge would improve your horticultural production and income if these were accessible in this area? *List multiple* | 1. ______________<br>2. ______________<br>3. ______________ |

Section II. IRRIGATION

| | | | |
|---|---|---|---|
| 13 | How many acres of crops do you irrigate? | | |
| 14 | What crops do you currently irrigate? | ............<br>............<br>............ | ............<br>............<br>............ |
| 15 | What irrigation system do you currently use?<br>List all that apply | None ☐<br>Manual ☐<br>Mechanical ☐<br>Petrol/diesel pump ☐<br>Solar pump ☐<br>Others (specify).............. | |
| 16 | How long have you been using this system? | | |
| 17 | How did you acquire the technology? | Individual purchase<br>Co-ownership<br>Borrowed<br>Leased/rented<br>Govt/NGO donation<br>Others (specify).............. | |
| 18 | How much does/did the system cost? | | |
| 19 | How did you pay or access finance for the system? | | |
| 20 | How much does it cost to run your pump daily and weekly? | Per day:<br>Per week: | |
| 21 | What are the reasons for acquiring this system over other existing irrigation systems? | | |
| 22 | What are your key challenges to adopting improved irrigation systems? | 1. ............<br>2. ............<br>3. ............ | |
| 23 | Did the system come with a financing scheme?<br>If yes, describe. | YES ☐ NO ☐<br>..................... | |
| 24 | Does the system fully meet your irrigation capacity and needs? *If no, why not?* | YES ☐ NO ☐<br>..................... | |
| 25 | What sources of water are available to you for irrigation? | 1. .............<br>2. .............<br>3. ............ | |
| 26 | Do you use water from a well for irrigation?<br>If yes, go to question 25 | YES ☐ NO ☐ | |
| 27 | If you use a well, how deep is it in meters? | | |

| | | | |
|---|---|---|---|
| 28 | How far is your main irrigation water source from your horticultural field in meters or kilometres? | In meters: .............m<br>In kilometers: ..........km | |
| 29 | Are these water source available throughout the year? | | |
| 30 | What is your irrigation schedule? | Months/year: | Wks/month: |
| | | Days/weeks: | Hrs/day: |
| 31 | Can you increase your horticultural production from the current level? | YES ☐ NO ☐ | |
| 32 | What critical capital, inputs, knowledge and capacity is preventing you from doing this currently? | | |
| 33 | Quantify how much more produce can you attain and how much additional income you would generate under this intensification scenario? | | |
| 34 | Have you ever rented land for agricultural production? | YES ☐ NO ☐ | |
| 35 | Did you irrigate the rented land? | YES ☐ NO ☐ | |

| Farmer name: | | Village | | | District | | | Region | |
|---|---|---|---|---|---|---|---|---|---|

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Section III. HORTICULTURAL PRODUCTION | | | | | | | | |
| | Fill in the following inform on farmer's horticultural cropping, input use and irrigation. This is on a field basis. If farmer intercrops a field, ask for the indicative proportion and fill in as separate fields. If crops are grown multiples times/season per year, fill in crop for each cycle of cultivation, e.g. if cucumbers are grown three cycles a year, fill in three rows for cucumber and the corresponding input, production and irrigation data. The list of inputs per research area will differ, field teams should change these to reflect their specific research context. | | | | | | | | |
| 36 | Production | | | | Input use (kg) | | | | Irrigation |
| | CROP | Area (acres) | Harvest (kg) | Season | *Fertilizer 1 (specify) | *Fertilizer 2 (specify) | *Fertilizer 3 (specify) | Other inputs (e.g. biocides) | Frequency per week |
| | | | | | | | | | |
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| | Notes: *Specify the common external inputs used in the area. This counts for both chemical and organic (like manure and compost). Use availability and access differs per zone and this is why no fixed set of inputs are specified. | | | | | | | | |

## Appendix 2: Descriptive statistics of farmers surveyed

N= number of observations; Std. dev= standard deviation; Min= minimum value detected in the sample; Max= maximum value detected in the sample.

| Item/variable | N | Min. | Max. | Mean | Std. Dev. |
|---|---|---|---|---|---|
| Number of adults in farming household | 390 | 1.00 | 15.00 | 3.46 | 1.72 |
| Total farm size (acres) | 407 | 0.25 | 17.00 | 3.84 | 3.24 |
| Labour proportion (fraction) | 317 | - | 1.00 | 0.54 | 0.29 |
| Proportion of produce sold (fraction) | 407 | 0.10 | 1.00 | 0.71 | 0.23 |
| Irrigated horticultural area (acres) | 407 | - | 17.00 | 1.82 | 1.84 |
| Annual capital expenditure (T SH) | 408 | - | 5,000,000 | 175,153 | 369,784 |
| Depth of well (m) | 203 | - | 180 | 11 | 21.28 |
| Distance from field to water source (m) | 400 | - | 10,000 | 383. | 1,074 |
| Proportion of farmers that have irrigated rented land (fraction) | 404 | - | 1.00 | 0.49 | 0.50 |
| Number of crops cultivated per grower | 407 | 1.00 | 7.00 | 2.61 | 1.33 |
| Area per crop (acres) | 407 | 0.00 | 10.00 | 0.92 | 1.14 |
| Tomato, Gross irrigation need (L/hr) | 407 | - | 16,827 | 991 | 1,964 |
| Cabbage, Gross irrigation need (L/hr) | 407 | - | 4,720 | 77 | 409 |
| Tubers, Gross irrigation need (L/hr) | 407 | - | 920 | 4 | 58 |
| Other vegs, Gross irrigation need (L/hr) | 407 | - | 16,739 | 1,121 | 1,975 |
| Total gross irrigation need – TGIN (L/hr) | 407 | - | 22,599 | 2,194 | 2,898 |
| Tomato revenue US$ | 407 | 0.00 | 16,062 | 823 | 1,614 |
| Cabbage revenue US$ | 407 | 0.00 | 3,122 | 64 | 310 |
| Other vegs revenue US$ | 407 | 0.00 | 10,556 | 1,346 | 1,425 |
| Root/tubers revenue US$ | 407 | 0.00 | 80 | 0.49 | 5.80 |
| Total horticulture revenue US$ | 407 | 0.00 | 22,625 | 2,233 | 2,369 |
| Total horticulture revenue T SH (million) | 407 | 0.00 | 52 | 5 | 53 |

## Appendix 3. Regulatory/policy environment

There are four main areas of policy that are relevant to the market development of SWPs for agricultural irrigation purposes in Tanzania:

1. Irrigation.
2. Energy.
3. Agriculture (with application to horticulture).
4. Trade Standards (for production and importation of equipment and parts).

Table A1 summarises the relevant actors and current policies. Although there are overarching national plans that may involve all four angles – for example, Tanzania Development Vision 2025 and the Sustainable Development Goals (SDGS) – the implementation details of these overarching polices are difficult to connect to practical, actionable information affecting the SWP industry. Therefore, only those policies that are directly connected with the use of solar energy and irrigation are mentioned.

*Table A3.1. Regulatory/policy environment relevant to market development of SWPs for agricultural irrigation*

| Policy area | Key Actors | Relevant policies/functions | Sources |
|---|---|---|---|
| Irrigation | Ministry of Agriculture (MoA)<br>Ministry of Finance and Planning (MFP)<br>National Irrigation Commission (NIRC)<br>Zonal and Regional Irrigation Offices (ZIO and RIO)<br>District Agriculture, Irrigation and Cooperatives Officer (DAICO)<br>Private parties<br>Irrigators' Associations and Cooperatives | At a national level:<br>*National Irrigation Policy (NAP, 2010 to date):* Covers all areas of irrigation interventions. Guidance is specific to the irrigation scheme (e.g. traditional, improved, smallholder, commercial).<br>*National Irrigation Act (2013 to date):* Law specifically focused on irrigation development, establishes the NIRC and facilitates construction of irrigation infrastructure.<br>*National Irrigation Development Strategy (2013-draft)*: proposed to run until 2028. In general terms, the strategy tackles: investment, management, R&D, production, training, institutions and financial mechanisms.<br>Related Water Policies:<br>National Water Policy<br>National Water Sector Development Strategy 2006-2015<br>Water Sector Development Programme 2006-2025<br>Water Resources Management Act, 2009 | (FutureWater, 2012; National Bureau of Statistics, 2015; Japan International Cooperation Agency, 2018) |
| Energy | Ministry of Energy and Minerals (MEM)<br>Rural Energy Agency<br>Energy and Water Utility Regulatory Authority (EWURA)<br>Tanzania Electric Supply Company Limited (TANESCO)<br>Tanzania Commission for Science and Technology (COSTECH) | At a national level:<br>*National Energy Policy (2015):* Addresses the energy sector challenges and optimal use of the energy resources.<br>*Electricity Act (2008, 2009):* focuses on expansion of electricity grid and development of off-grid electricity supply systems, including renewables.<br>*Rural Energy Act (2005):* established the autonomous Rural Energy Board and the Rural Energy Agency (REA), tasked with promoting access to energy services and the provision of subsidies for rural energy, including renewable energy systems.<br>*Energy and Water Utility Regulatory Authority Act (2001):* assigns the responsibility of energy tariff | (National Bureau of Statistics, 2017; World Future Council, 2017; Energypedia UG, 2018) |

| | | | |
|---|---|---|---|
| | Centre for Sustainable Energy Services (TaTEDO)<br><br>NGOs (African Development Bank, Bill and Melinda Gates Foundation, FAO/WFP, GIZ, GVEP, SNV, UNDP, USAID, World Bank)<br><br>Private parties<br><br>Industry Associations: Tanzania Renewable Energy Association (TAREA) | setting (including the independent renewable energy power producers) to the regulator.<br><br>At a project/program level:<br><br>*Second Generation SPP Framework:* covers the development of hydro, biomass, wind, and solar energy projects of capacity ranging from 100kW - 10MW. | |
| Agriculture (horticulture) | NGOs: AfDB, EU, GIZ, IFAD, Irish Aid, JICA, USAID, World Bank[70]<br><br>Private parties<br><br>Industry Associations:<br><br>Agriculture Council of Tanzania (ACT)<br><br>Tanzania Horticulture Association (TAHA) | At a national level:<br><br>*Agricultural Sector Development Strategy 2 (ASDS2, 2015-2025):* focusing on higher investments, productivity improvements, private sector involvement and regional trade (EAC, SADC). Horticulture is mentioned as a high-value opportunity for diversification and as a target for improved irrigation.<br><br>At a project/program level:<br><br>*Agricultural Sector Development Strategy 2 (ASDS2, 2016-2026):* focusing on commercialization, value chains, value addition, commodity and area-based interventions and private sector mobilization.<br><br>*Tanzania Horticultural Development Strategy 2012-2021*: identified key areas in need of direct investments, policy changes and infrastructural improvement. The issues included financing, water supply and irrigation systems. | (Mkindi, 2011; Japan International Cooperation Agency, 2018) |
| Trade Standards | Tanzania Bureau of Standards (TBS)<br><br>Manufacturers and importers of goods | TBS is the statutory national standards body for Tanzania, mandated to formulate, promulgate and implement national standards. It enacts the *Standards (Certification) Regulations 2009* through 8 Standards Committees. The most relevant is the Electrical Engineering Divisional Standards Committee (EEDC), with a technical committee EEDC 5 - Solar PV systems. Also, the Mechanical Engineering Divisional Standards Committee (MEDC) has a MEDC 10 - Farm Implements technical committee.<br><br>TBS also issues certification for manufactured products (e.g., ISO 9000) and represents Tanzania in all international standards work. TBS is the National Enquiry Point for WTO-TBT/SPS Agreements in Tanzania. TBS also manages information on technical regulations, adopted and proposed standards, conformity assessment procedures, and sanitary and phytosanitary measures. | (Tanzanian Bureau of Standards, 2018) |

[70] Note: not all of these parties have been involved in horticultural projects; some have dedicated funds to grains.

## Appendix 4. A-priori segmentation approaches

Segmentation by Market Orientation

Assuming that our sample proportions reflect the horticultural sector in the country, the market size is segmented as presented in Table A4.1.

Table A4.1. Market size per segment based on the Market Orientation model, forecasted for 2018 and 2022 (in US$).

| Market segment (US$) | 2018 | 2022 |
|---|---|---|
| **Subsistence farmers** | 1,724,627 | 3,026,148 |
| **Loosely market oriented** | 24,748,395 | 43,425,224 |
| **Market oriented** | 25,869,402 | 45,392,220 |
| **Commercial** | 33,888,917 | 59,463,809 |
| **TOTAL MARKET SIZE** | 86,231,342 | 151,307,401 |

| | Market Segmentation | SWP Design Parameters | Farming Activities | Irrigation Technologies | Water sources | Customer profile & key purchase decisions factors |
|---|---|---|---|---|---|---|
| | Large & export companies | Cultivated land above 100 hectares<br>Cultivated land above between 10- 100 hectares | Groups not investigated in this survey | | | |
| 39.3% of total sample (N=160) | Commercial | -Irrigated land between 0.1 - 6.9 hectares (avg =0.8 ± 0.9 ha)<br>-High gross irrigation needs (avg =2,049 ± 2,834 L/hr)<br>-Mid CAPEX levels (avg = TSh200,808 ± 456,650)<br>-Medium annual revenue levels (avg = TSh 5.1 million ± 5.7)<br>-Long distance from field to water source (avg = 938.4 ± 1,754.9 m)<br>-Mid-depth wells (avg = 8.0 ±10.8 m) | Mix of high-volume (tomato 25%, cabbage 3%) and high value (others 72%) vegetable production | Manual pumps: 49.5%<br>Canal: 6.5%<br>Diesel:35.9%<br>Mechanical: 3.8%<br>Others: 0.5%<br>None:3.8% | Surface water(rivers, streams, etc):47%<br>Hand-dug well: 40%<br>Borehole: 6%<br>Rainfed (all types):5%<br>Canals:2% | -76% have water available all year round<br>-63% are dissatisfied with their current system<br>**Top Five Factors of Purchase:**<br>-Cost/affordability (29%)<br>-Availability (17%)<br>-Simplicity of use (14%)<br>-Matches irrigation needs (7%)<br>-Lack of awareness of other types (6%) |
| 28.7% of total sample (N=117) | Market oriented | -Irrigated land between 0.1 -6.5 hectares (avg = 0.8 ± 0.9 ha)<br>-High gross irrigation needs (avg =2,526 ± 3,605 L/hr)<br>-Low CAPEX levels (avg = TSh144,269 ± 342,695)<br>-Medium annual revenue levels (avg = TSh 5.4 m ± 6.5)<br>-Long distance from field to water source (avg = 938.4 ± 1,754.9 m)<br>-Mid-depth wells (avg = 7.4 m ±5.8) | Mix of high-volume (tomato 23%, cabbage 4%) and high value (others 72%) vegetable production | Manual pumps: 36.7%<br>Canal: 36.7%<br>Diesel:18.7%<br>Others: 7.2%<br>None:0.7% | Surface water(rivers, streams, etc): 65%<br>Hand-dug well:31%<br>Canals:4%<br>Rainfed (all types):1% | -64% have water available all year round<br>-34% are dissatisfied with their current system<br>**Top Five Factors of Purchase:**<br>-Cost/affordability (37%)<br>-Dependence on water source (19%)<br>-Availability (15%)<br>-Lack of awareness of other types (8%)<br>-Village dynamics (5%) |
| 30% of total sample (N=122) | Loosely market oriented | -Irrigated land between 0.1 -2.8 hectares (avg = 0.7 ± 0.5 ha)<br>-High gross irrigation needs (avg = 2,215 ± 2,182.5 L/hr)<br>-Low CAPEX levels (avg = TSh179,920 ± 263,285)<br>-Medium annual revenue levels (avg = TSh5.1 m ± 3.8)<br>-Short-to-medium distance from field to water source (avg = 175.2 ± 507.2 m)<br>-Deep wells (avg = 18.1 m ±35.6) | Mix of high-volume (tomato 25%, cabbage 3%) and high value (others 72%) vegetable production | Diesel pumps: 50.7%<br>Manual pumps: 31.3%<br>Canal: 14.9%<br>Others: 2.2%<br>Mechanical: 0.7% | Surface water(rivers, streams, etc): 49%<br>Hand-dug well:38%<br>Borehole: 5%<br>Canals:5%<br>Rainfed (all types):3% | -75% have water available all year round<br>-66% are dissatisfied with their current system<br>**Top Five Factors of Purchase:**<br>-Cost/affordability (29%)<br>-Availability (25%)<br>-Dependence on water source (10%)<br>-Simplicity of use (10%)<br>-Matches irrigation needs (6%) |
| 8% of total sample (N=8) | Subsistence farmers | -Irrigated land between 0.1 hectares to 0.8 hectares (avg = 0.2 ± 0.09 ha)<br>-Low gross irrigation needs (avg = 288 ± 479.3 L/hr)<br>-Low CAPEX levels (avg = TSh158,500 ± 312,057)<br>-Low annual revenue levels (avg = TSh1.5 m ± 2.5)<br>-Short distance from field to water source (avg = 18.7 ±22.7 m)<br>-Shallow depth of well (avg = 3.5 ±0.7 m) | Mix of high-volume (tomato 22%) and high value (others 78%) vegetable production | Manual pumps: 33%<br>Rainfed: 33%<br>Diesel pumps: 23%<br>Canal: 11% | Surface water(rivers, streams, etc):36%<br>Rainfed (all types):27%<br>Hand-dug well:18%<br>Borehole: 9%<br>Canals:9% | -57% have water available all year round<br>-63% are dissatisfied with their current system<br>**Top Five Factors of Purchase:**<br>-Cost/affordability (33%)<br>-Dependence on water source (22%)<br>-Simplicity of use (11%)<br>-Village dynamics (11%)<br>-Seasonality (11%) |

Figure A4.1. Market segmentation model based on farmers' market orientation.

Segmentation by Irrigation Technology

Assuming that our sample proportions reflect the horticultural sector in the country, the market size is segmented as presented in Table A4.2.

Table A4.2. Market size per segment based on the Irrigation Technology model, forecasted for 2018 and 2022 (in US$).

| Market segment (US$) | 2018 | 2022 |
|---|---|---|
| **Manual** | 35,354,850 | 62,036,035 |
| **Diesel** | 30,612,126 | 53,714,128 |
| **Canal** | 15,780,336 | 27,689,254 |
| **Mechanical** | 1,724,627 | 3,026,148 |
| **TOTAL MARKET** | 83,471,939 | 146,465,565 |

| | Market Segment | SWP Design Parameters | Farming Activities | Market Orientation | Water sources | Customer profile & key purchase decisions factors |
|---|---|---|---|---|---|---|
| 36% of total sample (N=163) | Diesel pump users | -**Irrigated land** between 0 - 17 hectares (avg =0.9 ± 0.8 ha)<br>-High **gross irrigation needs** (avg =2,659 ± 2,900 L/hr)<br>-Mid-**CAPEX** levels (avg = TSh 338,278 ± 458,588)<br>-High **annual income levels** (avg = TSh 6.2 million ± 6.2)<br>-Mid-**distance from field to water source** (avg = 303 ± 786 m)<br>-**Deep wells** (avg = 17 ±31 m) | Mix of high-volume (tomato 37%, cabbage 4%) and **high value (others 58%)** vegetable production | Subsistence farmers:1%<br>**Semi-commercial smallholder: 42%**<br>Commercial smallholder: 17%<br>**Medium size (emerging) farmer: 40%** | **Surface water(rivers, streams, etc): 50%**<br>**Hand-dug well:39%**<br>Borehole:6% | -81% have water available all year round<br>-50% are dissatisfied with their current system<br><br>**Top 3 Factors of Purchase:**<br>-Availability (25%)<br>-Cost/affordability (14%)<br>-Dependence on water source/Simplicity (11% each) |
| 2% of total sample (N=8) | Mechanical pump users | -**Irrigated land** between 1 -2 hectares (avg = 0.5 ± 0.1 ha)<br>-Low **gross irrigation needs** (avg = 688 ± 466 L/hr)<br>-Mid- **CAPEX** levels (avg = TSh 321,250 ± 117,283)<br>-Mid- **annual income levels** (avg = TSh 3 m ± 0.9)<br>-Short **distance from field to water source** (avg = 21 ± 36 m)<br>-Mid-**depth wells** (avg = 7 m ±6) | Mix of high-volume (tomato 27%, and **high value (others 73%)** vegetable production | Subsistence farmers:1%<br>Semi-commercial smallholder: 24%<br>**Commercial smallholder: 61%**<br>Medium size (emerging) farmer: 14% | **Hand-dug well:40%**<br>**Surface water(rivers, streams, etc): 27%**<br>Borehole:20% | -88% have water available all year round<br>-75% are dissatisfied with their current system<br><br>**Top 3 Factors of Purchase:**<br>-Availability (36%)<br>-Cost/affordability (18%)<br>-Simplicity of use (18%) |
| 18% of total sample (N=84) | Canal irrigation users | -Irrigated land between 0.2 - 17 hectares (avg = 1 ± 1.2 ha)<br>-High **gross irrigation needs** (avg =2,488 ± 3,834 L/hr)<br>-Mid-**CAPEX** levels (avg = TSh 224,417 ± 678,686)<br>-High **annual income levels** (avg = TSh 7 m ± 9)<br>-Long **distance from field to water source** (avg = 1,091 ± 1,879 m)<br>-Mid-**depth wells** (avg = 9 m ±4) | Mix of high-volume (tomato 30%, cabbage 5%) and **high value (others 65%)** vegetable production | Subsistence farmers:0%<br>Semi-commercial smallholder: 13%<br>Commercial smallholder: 0%<br>**Medium size (emerging) farmer: 88%** | **Surface water(rivers, streams, etc): 75%**<br>**Hand-dug well:12%** | -60% have water available all year round<br>-61% are dissatisfied with their current system<br><br>**Top 3 Factors of Purchase:**<br>-Cost/affordability (27%)<br>-Dependence on water source (20%)<br>-Availability (19%) |
| 41% of total sample (N=188) | Manual system users | -**Irrigated land** between 0.3 hectares to 6 hectares (avg = 0.6 ± 0.5 ha)<br>-Mid- **gross irrigation needs** (avg = 1,924 ± 2,645 L/hr)<br>-Low **CAPEX** levels (avg = TSh 64,280 ± 165,802)<br>-Mid- **annual income levels** (avg = TSh 4.2 m ± 3.9)<br>-Short **distance from field to water source** (avg = 216 ±813 m)<br>-Mid-**depth wells** (avg = 7 ±11 m) | Mix of high-volume (tomato 39%) and **high value (others 61%)** vegetable production | Subsistence farmers:2%<br>**Semi-commercial smallholder: 30%**<br>Commercial smallholder: 29%<br>**Medium size (emerging) farmer: 39%** | **Surface water(rivers, streams, etc):53%**<br>**Hand-dug well:36%**<br>Borehole: 4%<br>Canals: 4% | -72% have water available all year round<br>-59% are dissatisfied with their current system<br><br>**Top 3 Factors of Purchase:**<br>-Cost/affordability (31%)<br>-Availability (19%)<br>-Dependence on water source (12%) |

Figure A4.2. Market segmentation model based on Irrigation Technology.

## Appendix 5. Pre-requisites for adoption of SWPs

There were specific questions in the individual farmers' questionnaires that aimed to uncover the major challenges in horticultural development and attitudes to adoption of new technologies for irrigation, such as SWPs. All responses relevant to identifying key pre-requisites for adoption of SWPs were analysed to find common themes, using the *Nvivo* software to analyse text-based open responses. A narrative of the responses to the questions of interest in this section emerged from these figures:

**Future improvements:** During the individual farmer surveys, the FGDs and the stakeholders interviews, it transpired that market uncertainty is a main concern of horticultural growers. It is therefore not surprising that acquiring knowledge is core to the farmers' future aspirations regarding their operations. The collected responses in this question constantly refer to acquiring better market knowledge, agricultural/ horticultural education, knowledge of new irrigation technologies, and more information about how to best use their inputs. Improved irrigation technology was also mentioned.

**Key challenges in the adoption of SWPs**. Lack of awareness, lack of capital and general uncertainty about how SWPs work and are maintained, were general themes in this question. These challenges for SWPs correlate well with some key drivers of purchase, namely lack of awareness of other types of irrigation technologies and cost/affordability. Some farmers thought that their small operations did not justify the cost (because the assumption is that SWPs will be more expensive than other types). Some farmers mentioned that they only farmed during the rainy season because during the dry season they do not have water sources available for their crops, although it was already established that these farmers represent a small proportion of the total.

During the stakeholder interviews, the following question addressed the issue of pre-requisites for SWP adoption:

What are some pre-conditions and infrastructural investments needed to improve the chances of accelerating (solar) irrigation uptake?

Again, we used Nvivo to find the underlying themes in the stakeholder responses. The pre-requisites identified by key stakeholders were:

- Availability of water. Dams, shallow wells.
- Access to capital.
- Land, with a view of using it as a guarantee for credit.
- Financial and technical assistance.
- Physical facilities for demonstration of irrigation equipment.
- Drip irrigation systems and other irrigation technologies.
- A less uncertain market for the farmers produce.
- Government subsidies.
- Farmers groups.

*Table A5. 1. Central themes and typical grower responses collected regarding irrigation and pumps, plus implications for the marketing of SWPs.*

| Question | Theme | Typical statements | What does it mean in terms of pre-requisites and value propositions for SWPs? |
|---|---|---|---|
| **Elements for future improvement (positive statements)** | Irrigation | "Improvement in irrigation equipment "<br>"Knowledge on how to use improved irrigation equipment"<br>"Education about irrigation technology"<br>"Introduce new irrigation technology" | Farmers would switch to an irrigation solution that brings them a better level of performance than the system they already use. Further, they also want added services, such as training. Knowing that the company will not leave them alone with an equipment that they don't know how to use is also be important, so ensuring presence on-the-ground should be part of the marketing strategy for SWPs. Low operating costs of solar pumps can be a strong advantage over diesel pumps. |
| | Pumps | "Marketing presence concerning the new technology and improved pumps that operate at low costs"<br>"Solar water pump and loans accessibility"<br>"Availability and education on how to use those improved solar pumps"<br>"Introduction of modern methods and affordable pumps"<br>"Bring us new technology like solar pumps and market for our produce" | |
| **SWPs adoption challenges (negative statements)** | SWPs | "Very expensive to acquire"<br>"Lack of capital to establish system"<br>"Availability of new adopted system"<br>"Capital needed and knowledge"<br>"No education of new system and high prices of system"<br>"They are not well known and they are expensive too"<br>"Current system is cheap, others like drips are expensive and use a lot of time"<br>"Pump maintenance"<br>"Lack of knowledge, skill to use them, lack of information" | The capital required to purchase a solar pump will be an important decision factor. A potential solution is offering finance instruments that the farmers will be comfortable with (e.g. rental agreements with an option to buy). Availability of spare parts with their preferred stockists will also be important.<br>The optimal target customer would be one that already uses pumps: it is difficult to convince a farmer that uses rain water or channel irrigation to switch to a costlier solution.<br>The lack of awareness on solar pump technology makes it hard for farmers to see the advantages over a diesel or manual irrigation approach. Frequent and geographically spread demonstrations of the technology will be needed. A brick-and-mortar demonstration centre might be a good idea in the future. However, such a centre would be a demanding project that would take resources away from a start-up company in Tanzania. It would be worth discussing with larger companies the concept of a demonstration centre for horticultural technologies, e.g. seed suppliers such as Rijk Zwaan, greenhouse technology suppliers and so on. |