AgWater Solutions Project
Case Study

Investment Opportunities for Water Lifting Technologies in Smallholder Irrigated Agriculture in Tanzania

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The AWM Project
The AgWater Solutions project was implemented in five countries in Africa and two states in India between 2008 and 2012. The objective of the project was to identify investment options and opportunities in agricultural water management with the greatest potential to improve incomes and food security for poor farmers, and to develop tools and recommendations for stakeholders in the sector including policymakers, investors, NGOs and small-scale farmers.

The leading implementing institutions were the International Water Management Institute (IWMI), the Stockholm Environment Institute (SEI), the Food and Agriculture Organization of the United Nations (FAO), the International Food Policy Research Institute (IFPRI), International Development Enterprises (iDE) and CH2MHill.

For more information on the project or detailed reports please visit the project website http://awm-solutions.iwmi.org/home-page.aspx.

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1. BACKGROUND

Agriculture in Tanzania remains the most important economic sector. It contributes 45% of Tanzania´s GDP and nearly 30% of its export earnings, while employing over 80% of the nation´s work force (URT, 2008). Food crop production dominates the agricultural economy. About five million hectares are cultivated annually, of which 85 percent is under food crops. Women constitute the main part of the agricultural labor force. The major constraint facing the agriculture sector is the falling labor and land productivity due to the application of poor technology and dependence on unreliable and irregular weather conditions. Both crops and livestock are adversely affected by periodic droughts. Irrigation holds the key to stabilizing agricultural production in Tanzania to improve food security, increase farmers' productivity and incomes, and also to produce higher valued crops such as vegetables and flowers. In the national framework, irrigation has been identified as one of the key strategies for growth and poverty reduction in Tanzania (Mow, 2009).

Tanzania has about 44 million hectares of land suitable for agriculture, out of which only 23 percent (10.2 million hectares) are utilized. Out of 29.4 million hectares of land suitable for irrigation, only 289,245 hectares (1 percent) was under formal irrigation by the end of 2008. Tanzania has 62,000 sq. km of the fresh water resources available for crops, livestock and fish farming, which is grossly underutilized. Irrigation practice is dominated by small-scale irrigation and does not fully consider irrigation done outside irrigation schemes such as when small motorized pumps and other water lifting devices are used for irrigation. This is because the latter types of irrigation are seen as "informal" not only in Tanzania, but also in many Sub-Saharan African countries. The fact is however, that this kind of "informal" irrigation is increasingly used not only outside the schemes but even in the irrigation schemes to grow high value crops such as vegetables. In this study, we aimed *to understand these informal irrigation practices and investment opportunities for water lifting and application technologies (WLATs) among small-scale farmers in Tanzania.*

2. SETTING THE SCENE

2.1 WLATs in Tanzania

2.1.1 Introduction

There are many types of water lifting and application technologies in use in Tanzania. They differ in scale, complexity and origin. For example, water lifting was traditionally done by the "rope and bucket system" system and is now transitioning to the use of mechanized boreholes. Or even better, with increased knowledge on climate change, there are initiatives on developing renewable energy based systems like wind and solar powered pumps. For water application technologies, farmers have moved from manual applications using buckets to sophisticated pressurized drip irrigation systems. A discussion on every form of WLAT in Tanzania will be difficult to present in this report. However, in this section, a highlight of some innovative WLATs is presented.

2.1.2 Treadle pumps

In Tanzania, there are three main types of treadle pumps used by farmers. These are the MoneyMaker pumps, hip pumps and Concrete Peddle Pumps (PEP). Moneymaker and hip pumps are products from Kick Start International, while PEP pumps are from an NGO called Water for Third World Countries (W-3-W).

2.1.2.1 Moneymaker and Hip Pumps

Moneymaker pumps are foot-peddled while hip pumps are hand-operated with support from hips (see Figure 1). The hip pump allows users to use their legs, body weight, and momentum, rather than the small muscles of the upper back and shoulders. They both have steel casings with rubber valves. The key design features are summarized in Table 1. Moneymaker pumps are used by thousands to pump water from hand-dug wells, rivers, streams, lakes and ponds. It is ideal for sprinkler irrigation, filling overhead water tanks, or for use with nozzles and sprays attached to the end of the delivery hose. In Tanzania, most farmers use streams and ponds as their source of irrigation water while using and application is done directly using water hoses.

Table 1. Key design features of money maker pump.

	Super MoneyMaker	Hip Pump
Water suction depth	7 m	7 m
Total pumping head	14 m	14 m
Land irrigated	0.81 ha	0.51 ha
Distribution distance (flat area)	200 m	200 m
No. of sprinklers it can serve (when used with sprinklers)	5	3
Weight	21 kg	4.5 kg

2.1.2.2 Concrete Pedal Pump (PEP)

PEP is a foot-driven pedal pump used to draw water for agricultural irrigation or domestic uses. It can draw water from a depth of 8 m vertically and more than 400 meters horizontally. The discharge rate can reach 100 l/min. The pump body is made of concrete with a metallic cylinder inside with a rubber (or plastic) piston ring. A rubber foot valve permits water to enter and closes when the piston goes down. The device cannot rust and is easy to produce locally. Most pumps in Tanzania are installed on wooden platforms at a height of around 1 m. This base is built by the farmers but with assistance from the manufacturer. There are also permanent installations such as a concrete cistern that can provide water directly to a distributor canal. The pump is provided with a PVC suction pipe (diameter 1.5 inches) with a length depending on the distance to the water, generally ranging from 3 to 25 m. After pump assembly, an accompanying storage system is installed. Normally, it consists of a 200-liter drum but it can also be a bigger storage facility (such as a 2 m^3 metallic tank). A typical PEP installation with wooden platform is shown in Figure 1, with photos showing actual use in the field for watering and irrigation.

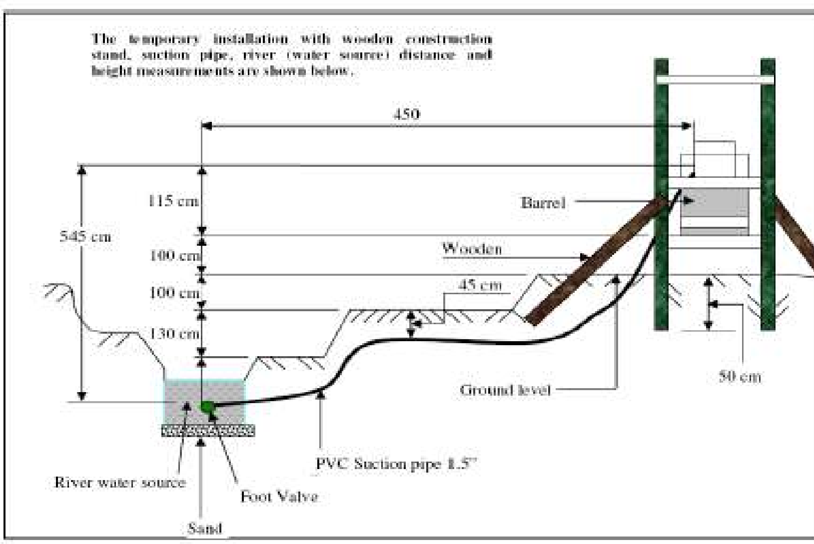

Figure 1: Schematic diagram showing the installation of PEP
Source: IPTRID (2008).

2.1.3 Small motorized pumps

Motorized pumps are becoming more common in smallholder farming systems in Tanzania. The pumps have become increasingly popular for irrigating staple crops like maize due to long dry spells experienced in Tanzania such as the one in 2009. The capacity of pumps ranges from 3.5-6.5 HP. Traditionally, many farmers used Japanese brands such as Honda, but of late, there are more Chinese pumps in the market with many brand names. In Tanzania, water application from small motorized pumps is commonly done by the use of a water hose, just like in treadle pumps.

2.1.4 Wind and solar pumps

Some organizations which support renewable energy initiatives are promoting windmills and solar pumps for agricultural use in Tanzania. Most of these initiatives are around the Lake Victoria region. For example, under the UNDP funded Development for Energy in Africa project, the Tanzania Traditional Energy Development and Environment Organization (TaTEDO) implemented and studied the use of solar and wind pumps in some smallholder irrigation schemes in Ukerewe District, where farmers get water from Lake Victoria. Some other local NGOs like SASEDO have been involved in "The Application of Renewable Energy for Irrigation Farming", whereby they are facilitating the design and production of low-cost renewable energy systems based for water pumping systems. They focus on the application of renewable energy, such as small wind driven water pumping systems and solar water pumps for irrigation purposes, to replace the current petrol and diesel pumps to save water, fuel and CO_2 emissions in conjunction with the introduction of efficient irrigation methods for increased farm production.

Solar Panels and windmills for irrigation in Mwanza (Photo Credit: SASEDO Tanzania).

2.1.5 Hydram pumps

Although their use is limited in Tanzania, hydram systems are used in some locations, especially in the hilly parts of Mbeya Region. A hydram is an automatic pumping device which uses a small fall of water to lift a fraction of the supply flow to a much greater height. The main virtue of the hydram is that it has few moving parts, and is therefore extremely mechanically simple, which results in very high reliability, minimal maintenance requirements and a long operational life. Its mode of operation depends on the use of the phenomenon called a “water hammer” and the overall efficiency can be quite good under favorable circumstances. In a typical hydram installation, a supply head is created either by digging a small contoured diversion canal bypassing a river, or in some cases, particularly with small streams, it is normal to create a weir and to install the hydram directly below it. Where greater capacity is needed, it is common practice to install several hydrams in parallel. This allows a choice of how many to operate at any one time so it can cater for variable supply flows or variable demand.

2.1.6 Drip irrigation

This can be described as a water delivery system that involves application of water into the soil through a small sized opening directly on the soil surface, where the crop is planted. This is achieved by applying water at a very slow rate. It enables the use of limited amounts of water and fertilizer can be applied together with the irrigation water to grow high value crops (e.g. watermelons, tomatoes, onions). For this drip system the water application to plants is by gravity and a small pump (powered or manually operated, e.g. treadle pump) is needed to pump water from an underground source into a storage tank with a capacity of about 200 to 1000 liters and raised 1.5 m above ground.

In Tanzania this technology has been promoted since 2003. The importation, promotion, selling, and distribution is done by a private company, namely Balton Tanzania Ltd with offices in Arusha. The promotion is done through different mechanisms, including agricultural shows, TV, radio, and newspapers. The system and components are imported from Israel and Germany. Balton assists farmers who purchase the system with installation. In some instances where farmers purchase the system after being sensitized by the government irrigation agency the installation assistance is also provided by the agency.

Drip irrigation system in Tanzania (Photo Credit: MoWI)

Since the promotion of the technology started in 2003, more than fifteen farmers have installed the system in Arusha, Kilimanjaro, Manyara, Coastal and Ruvuma Regions on the mainland. Farmers have installed different family drip system sizes ranging from system covering 500 m^2 to 2000 m^2. The families that have installed the drip system can be regarded as well off families because the systems are relatively expensive. For example, a system covering 500 m^2 costs TZS 292,000.00. However it needs minimal labor and maintenance, which mainly involves replacement of filters. Despite the cost, it seems to be gaining popularity because of its low water use and minimal labor requirements. Farmers buying the system are located near town and city centers where labor is expensive, and ground water abstraction is becoming popular.

2.2 Where WLATs are mostly used in Tanzania

Irrigation using WLATs is predominant where horticulture is practiced. Tanzania has a large area suitable for horticulture but only a small portion of this is under cultivation. Regions with suitable conditions for vegetable cultivation are situated in Morogoro, Tanga, Iringa, Moshi, Arusha and Mbeya (Figure 2). The farms in the coastal zone are relatively small and not sufficient for supplying Dar es Salaam. The central plateau suffers too much from drought and poor infrastructure. Crops grown in this area are tomatoes, onions and sweet potatoes. In the lake zone, a lot of tropical fruits are grown and exported to neighboring countries. The highlands are best suited for vegetable production due to the varied climatic conditions, reliable and well distributed rainfall and possibilities for irrigation and the presence of relatively good roads for distribution (Swai, 1991). Based on soil and climatic factors (see Table 2), a suitability map for growing of vegetables mainly using soil and climatic factors was generated (Figure 2).

Table 2: Regions suitable for vegetable and potato/beans production in Tanzania.

Region	Vegetables	Potato/beans	Altitude (masl)	Precipitation (mm)	Area (sq-km)
Eastern plateaus and mountain blocks (west central-Tanga/Morogor)					
E7		X	750-1300	800-1000	40,961
E12	X	X	1000-2000	800-1000	2,752
E13	X	X	800-2000	800-1000	640
E14	X	X	500-2000	1000-1200	2,976
E15	X	X	800-1700	1000-1220	1,920
High plains and plateaus (South-Mbeya/Iringa)					
H1	X	X	1500-2000	600-700	13,137
H2	X	X	1500-2100	1400-1600	6,989
H3	X	X	1500-2300	1000-1200	13,137
H5	X	X	1200-2400	1000-2000	9,300
H6		X	2300-2700	1000-1200	790
H7		X	1500-2300	800-1000	18,438
Volcanoes and rift depressions (North-Arusha/Kilimanjaro)					
N1		X	1500-2500	600-700	6,114
N2		X	2000-2500	800-1000	1,060
N4	X	X	900-3500	500-600	3,686
N5		X	1300-1700	1000-1200	3,159
N10	X	X	1500-1800	1400-1600	724
Central Plateuas (Plains)					
P5		X	1100-1300	600-1000	67,855
P6	X	X	800-1800	600-1000	30,079
Ufipa plateau					
U		X	1400-2300	1000-1200	16,554
Western Highlands (west of lake Victoria)					
W1		X	1300-1800	800-1000	8,688
W2		X	1500-1700	1000-1200	13,427
W3		X	1200-1600	800-1000	6,690
W4		X	1400-1500	800-1200	10,622

Source: Anonymous, in AfriVeg (2007)

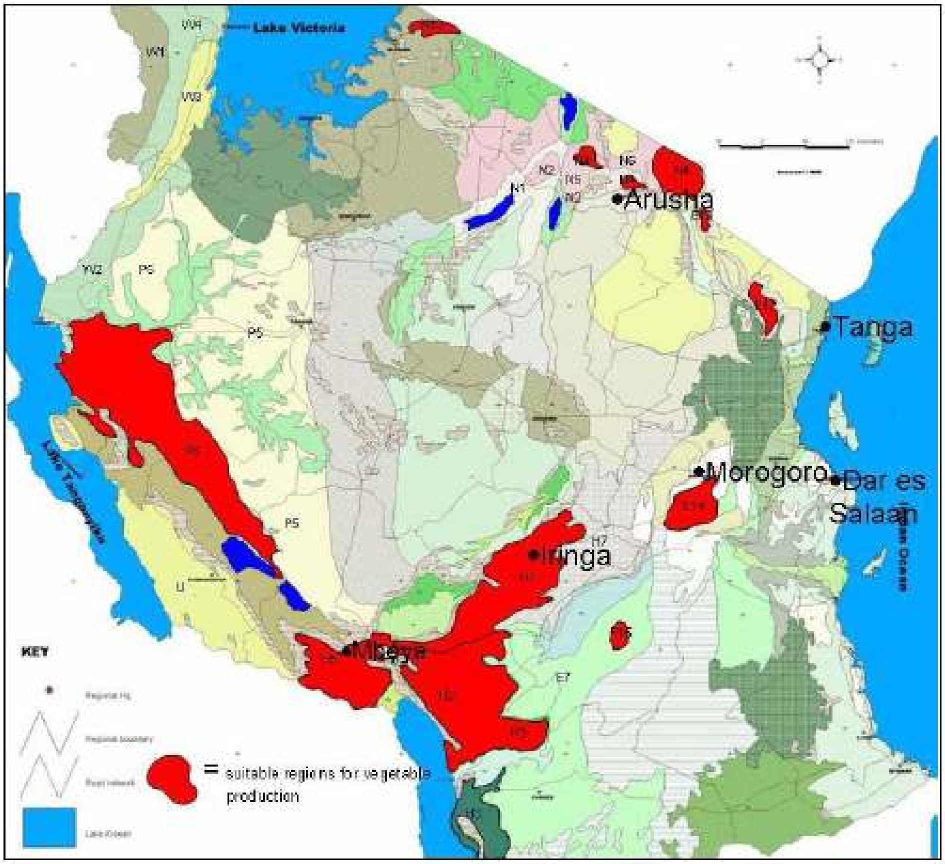

Figure 2: Regions suitable for vegetable production in Tanzania.
Source: Ministry of Agriculture and Food Security in AfriDev 2007

3. SOURCES OF INFORMATION

The information base on WLATs for irrigation in Tanzania is limited owing its “informality”. Nevertheless, to ensure reliability and validity of information presented in this report and time limitations for this study, multiple methods and the few available data sources were triangulated. Specific methods used included farmer surveys, interviews with key informants at relevant institutions, and interviews with supply chain dealers.

3.1 Farmer surveys

Farmer surveys were the main method used for the study. In Phase 1, a general reconnaissance survey was done in the main agricultural regions in Tanzania. This was followed by in-depth studies in five districts (in five different regions). Selection of these five locations was based on the extent of use of WLATs as observed in the first phase, agro-ecological zones and farming practices among other factors. These five locations were in and around Kipera (Mvemero District in Morogoro Region), Mpunguzi and Bihawana (Dodoma Urban District, Dodoma Region), Lukozi (Lushoto District, Tanga Region), Arumeru/Moshi Urban Districts in Arusha and Kilimanjaro Regions and also Kinondoni and Ilala in Dar es Salaam (see Figure 3).

These surveys were supported by cases from other communities surveyed in Tabora, Iringa, Mbeya and Pwani Regions. Details about these communities and characteristics of farmers’ interviews are elaborated in subsequent sections. In total, more than 335 farmers were interviewed. The questionnaire focused on six main areas: Socio-economic and demographic characteristics of farmers, water sources and water lifting devices, farming practices, decision making, productivity assessments, forward and backward linkages. Focus was on three main water lifting devices: motor pumps, treadle pumps and buckets. Respondents were farmers who were household heads and who were using any of the three water lifting devices in the current or year prior to the survey. Sampling was stratified according to their farming groups and gender. In all communities, rainfed farmers were used as controls. The questionnaire used is attached in Annex 1.

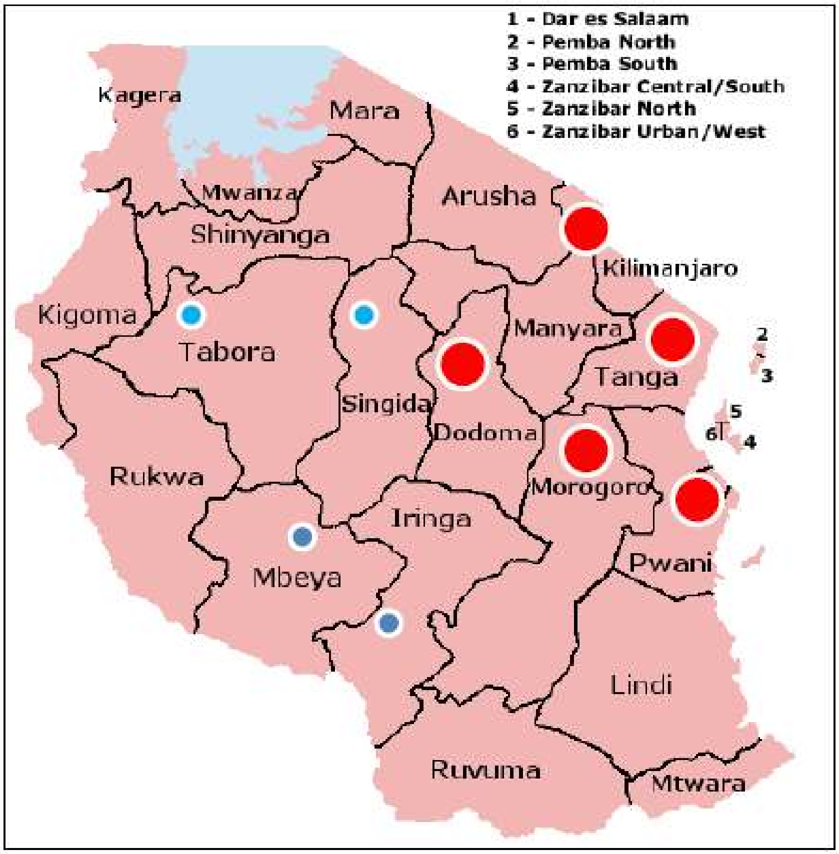

Figure 3. Map of Tanzania showing location of study communities.

3.2 Interviews with key informants at relevant institutions

Additional information was obtained from interviews with various key players in the irrigation sector, especially those who have a specific focus on WLAT systems. These included officials from the Ministry of Water and Irrigation, directors of NGOs involved in the manufacture and distribution of treadle pumps in Tanzania (Kickstart International and W-3-W), District agricultural (irrigation) officers, regional secretaries, and agricultural extension officers. Others interviewed were researchers from Sokoine University of Agriculture and University of Dar es Salaam. NGOs involved in agricultural development at community level such as World Vision International also provided useful information. In total, 22 key informants were interviewed.

3.3 Interviews with supply chain dealers

Dealers in manufacturing, distribution and repair of WLATs were also interviewed. A questionnaire was designed for this important group in the supply chain. Information collected included the types of pumps mostly sold, the numbers sold and other details to understand their operations and challenges that could hinder and facilitate accelerated motor pump adoption in Tanzania. Interviews were done with dealers of different scales and in most regional capitals and small towns where farmer surveys were conducted. A total of 36 dealers were interviewed. The questionnaire used is attached in Annex 2.

4. UNDERSTANDING INVESTMENT BENEFICIARIES

4.1 Description of main research locations

4.1.1 Dodoma – (Dodoma)

The two locations (Mpunguzi and Bihawana) are administrative wards of Urban Dodoma District. Dodoma is in the center of the country. Both have a semiarid climate with relatively warm temperatures throughout the year, while average highs are consistent throughout the year. Average lows can dip to 10 °C. Dodoma averages 570 mm of precipitation per year, the bulk of which occurs during its short wet season between December and March.

4.1.2. Lushoto and Muheza (Tanga)

Muheza and Lushoto are two of the eight districts in Tanga Region. Tanga Region, generally experiences two major rainfall seasons, one with long rains between March and May and another with short rains between October and December. The average annual rainfall varies between 200 mm and 2000 mm. Annual rainfall varies from year to year and between ecological zones. The part of Muheza District where this study was done is in the dry plains zone. The altitude of this zone ranges from 200 m to 600 m above sea level, with an average rainfall between 500 mm and 80 0mm per annum. The temperatures in this zone range from 21°C to 24°C annually. The soils are mainly brown-sandy. The major crops grown include sisal, cotton, tobacco, paddy, maize, cassava, millet and beans. Lukozi is in Lushoto which is in the mountainous zone on the slopes of the Usambara Mountains. The zone is located between 1000-2400 m above sea level. The temperature ranges between 210°C and 280°C. The annual rainfall ranges between 800-2000 mm. The soil is mainly red loamy clay. Major crops grown include coffee, tea, cardamom, maize, round potatoes, bananas, beans, spices, fruits and vegetables.

4.1.3 Arumeru/Moshi (Kilimanjaro)

Arumeru is one of eight districts in Arusha Region in northeastern Tanzania. The district has three major agro-ecological zones. These are the highlands, midlands and lowlands. This study was done in the highlands. The highland area is densely populated with an average of 157 people/km^2. The annual rainfall is about 1000 mm or more. The short rains occur in October to December, the long rains February to June. The highlands have the highest agricultural potential in the district with an altitude ranging from 1400 to 1800 m above sea level. Areas above 1000 m are dominated by medium fertile soils. The land is degraded with gullies and splash erosion. The major cash crops are coffee and pyrethrum. Food crops include bananas, maize (mostly hybrids), pigeon pea, beans, cowpeas, vegetables and potatoes. Livestock include cattle, goats and sheep in a semi-intensive zero-grazing system. The main soil is volcanic with some patches of red soil. The forest, managed as a water catchment, covers a large area.

4.1.4 Dar es Salaam

Dar es Salaam is on the coastal plains. Being situated so close to the equator and the warm Indian ocean, the city experiences generally tropical climate conditions, typified by hot and humid weather throughout much of the year. Dar es Salaam features a tropical wet and dry climate , with two different rainy seasons. Annual rainfall is approximately 1,100 mm and in a normal year there are two distinct rainy seasons: "the long rains", which fall during April and May, and "the short rains", which fall during October and November.

4.1.5 Mvomero (Morogoro)

The main study location was in Kipera village near Mzumbe University. Mvomero District is on the river valleys and basins agro-ecological climatic zone of Morogoro Region. The topography of these areas is predominantly plains with rainfall ranging between 900 mm and 1400 mm annually. Temperatures in this zone are high with an average of 30^0C due to its lowland nature. The zone is densely populated in the upper parts of the valleys and sparse in the inner parts. Major food crops include maize, paddy, sorghum, beans, cassava, fruits and vegetables. Cash crops are cotton, sisal, vegetables, oil seeds, sugar cane and coconuts.

4.2 Characteristics of farmers

Table 3 shows the main characteristics of farmers involved in the household surveys (the respondents, who could be typical beneficiaries from investments made in WLAT systems). Results show that more males were interviewed than females. As much as a gender balance was aimed at, it was hard to achieve it. It should also be noted that irrigated agriculture using WLATs is mainly a commercial activity and there is a tendency in Tanzania, as in many African countries, for men to be engaged more in commercial activities even if it is vegetable farming. Regardless of location; most respondents were married and educated to primary school level. The average age of the farmers was about 40 years and family sizes were between 4.5-6 persons per household, which is typical of Tanzania demographics.

Table 3: Demographic characteristics of survey respondents.

	Morogoro (n=111)	Tanga (n =59)	Dodoma (n =60)	Dares Salaam (n =56)	Kilimanjaro (n =49)
Gender of respondent					
Male	64.0%	76.5%	89.8%	91.0%	67.3%
Female	36.0%	23.5%	10.2%	9.0%	32.7%
Age of respondents	42.6(16-80)*	39.0(15-72)	37.8 (19-53)	41.3(22-69)	40.0(19-66)
Marital status					
Single	17.1%	6.7%	30.8%	6.8%	17.4%
Married	72.9%	93.3%	69.2%	93.2%	82.6%
Widow	10.0%	0.0%	0.0%	0.0%	0.0%
Educational level					
Informal	21.6%	2.0%	0.0%	7.5%	2.0%
Primary	70.3%	88.2%	93.2%	88.7%	85.7%
Secondary	8.1%	9.8%	6.8%	3.8%	12.3%
Tertiary	0.0%	0.0%	0.0%	0.0%	0.0%
No. of people in household	4.5(1-10)*	5.2(1 -14)	4.9 (1-9)	6.1 (1-21)	5.0 (1-12)

4.3 Contribution to household incomes

For irrigated farming households in Tanzania using WLATs, irrigated farming contributes more than 50% of the total household income (see Table 4). The proportion is less in study locations in Tanga and Morogoro, where farmers also do a lot of rainfed farming (usually paddy or maize, which they often sell for household income) and in Dar es Salaam, where farming incomes are supplemented by non-farming activities like small businesses. In study locations in Kilimanjaro (which included the Arusha site of Arumeru), most rainfed crops there were cereals (maize and beans), which were not sold, so vegetables planted were their main sources of income. In general, for this farmers irrigated agriculture using WLATs was a main livelihood.

Table 4: Contribution of farming type to household income.

Community	Irrigated farming *(%)*	Rainfed farming *(%)*	Other sources (%)
Morogoro	54.0	33.9	12.1
Tanga	61.4	20.7	17.9
Dodoma	76.2	11.8	12.0
Dar es Salaam	72.0	1.1	26.9
Kilimajaro	86.7	8.5	4.8

[a]Figures in parenthesis are ranges
n.a. – not applicable/practiced

4.3 Irrigated areas and crops

Cabbage and lettuce were the main irrigated crops in the study areas. Tomatoes were also common as irrigated crops. Other irrigated crops, especially in the highlands, were potatoes and green maize (Table 5). While areas under actual irrigation had no significant variation across study locations (0.35-0.57 ha), total land owned by households differed significantly. For example, in Morogoro and Dodoma, households had an average of 3-4 acres, but only 0.8-1.4 acres were actually irrigated. In Dodoma, the other parts of land were far away from the water sources and could not be cultivated due to low rainfall.

What is important is to compare potential irrigable areas with actual irrigation areas so as to assess the potential of spatial expansion. Actual irrigation areas in Dar es Salaam and Tanga are 95% of the total potential irrigable area, so they offer little room for spatial expansion. While in Lushoto, the limitation can be attributed to the steep slopes, so irrigated vegetable farming is limited to some valley bottoms with streams. In Dar es Salaam, the limitation is the city expansion. Morogoro and Tanga irrigate 80-90% of their potential irrigable areas which offers some room for spatial expansion. However, Dodoma, offers the greatest opportunity for spatial expansion because only two-thirds of the potential irrigable area is actually irrigated. Irrigation limitations in Dodoma are due to the dry climate and the distant water sources. Developing water sources in Dodoma could spur expansion of irrigated areas using WLATs. But, while spatial expansion in many locations other than Dodoma doesn't seem to be a promising opportunity, optimization of space by increasing productivity per area could offer better opportunities.

Table 5. Major crops and land sizes in study communities.

	Morogoro	Tanga	Dodoma	Dares Salaam	Kilimanjaro
	(n =111)	(n =59)	(n =60)	(n =56)	(n =49)
Major irrigated crops	Vegetables, Tomatoes	Potatoes, Vegetables, Tomatoes,	Vegetables, Green pepper, Tomatoes,	Vegetables, Tomatoes	Vegetables, Maize, Potatoes
Total area (ha)	1.54 ±1.26*	1.23 ±0.93	1.77 ±1.20	0.51 ±0.50	1.15 ±0.79
Mean area under cultivation (ha)	1.38 ±1.21	0.48 ±0.50	1.03 ±0.97	0.39 ±0.26	0.66 ±0.53
Potential irrigable land (ha)	0.69 ±0.89	0.45±0.31	0.53 ±0.39	0.38 ±0.48	0.54 ±0.11
Actual Irrigated Area(ha)	0.57 ±0.69	0.43 ±0.47	0.35 ±0.29	0.36 ±0.26	0.48 ±0.55

*Standard deviations n.a.- not applicable

4.4 Land ownership and decision making for farming activities

Most irrigated and non- irrigated plots were owned by men or jointly by men and women (Table 6). The findings show there were significantly higher numbers of females owning manually irrigated plots compared to plots where pumping systems were used (23.5% manual compared to 8.9% pumping). However, more women were involved in decision making on what to plant. The proportion of women who decided what to plant was higher among those who owned plots. This corresponded well with the question on who actually managed the plots. This finding could imply that more women were involved in the actual production of vegetables than men, especially on manual and rainfed systems, which was also observed during the study. On control of income from farming systems, pumping systems show more joint controls. However, we see more men moving in to control incomes in rainfed and manual systems compared to the proportions involved in production activities.

Table 6: Decision making in WLATs production systems.

	Pump technologies			Buckets			Rainfed		
	Male	Female	Joint	Male	Female	Joint	Male	Female	Joint
Who owns the land	46.4	8.92	44.6	49.0	23.5	27.5	47.4	15.5	37.1
Who decides what crop to plant	49.1	5.3	45.6	41.2	23.5	35.3	30.9	14.4	54.7
Who manages the farm	59.6	7.1	33.3	35.3	21.6	43.1	21.2	13.1	65.7
Who controls income	28.1	5.3	66.7	58.8	21.6	19.6	31.6	19.4	48.8

4.4 Water sources

Surface water (streams, rivers, irrigation canals) and shallow groundwater (shallow wells) were the major sources of water used for irrigation by the respondents. The differences in sources of water were not technology based but rather location based. For example, in Dodoma, which is drier and has limited water sources, regardless of the water lifting technology, farmers were using river water during the wet season and wells on streams during the dry season (see photo). These well-on-riverbed water sources on average are 2 m deep. In Morogoro, which had multiple sources, farmers could use different water sources depending on distance to their farms and technology used. Dugouts were, for example, dug within the fields and most commonly used for manual bucket irrigation, while pump technologies could use the dugouts or streams. In general, about 76% of the farmers were using surface water sources while the rest were using dugouts. These dugouts are usually about 1 m deep and 2 m in diameter.

Table 7 shows the average distances to water sources used in different locations. As indicated by the agro-ecological zone, farmers in Dodoma collected water from the furthest distances. Distances in Dar es Salaam were much shorter especially in urban areas where farming is done in low lying areas unsuitable for housing construction. In Kilimajaro, many farmers benefited from using canals that are used for formal river diversion systems.

Table 7. Distances to water sources.

	Morogoro	Tanga	Dodoma	Dar es Salaam	Kilimanjaro
Streams (m)	300	183	450	200	135
Dugouts (m)	67	30	115	40	80
Canal (m)	200	100	n.a.	n.a.	30

4.5 Costs of water lifting devices and accessories

The actual capital costs of water lifting devices and accessories as provided by farmers are shown in Table 8. The cost of motor pumps is on average three times that of treadle pumps. While the cost of treadle pumps has remained more less the same over the years, the cost of motor pumps is decreasing. This is due to the influx of cheap Chinese motor pumps in the market.

Table 8. Capital cost of water lifting devices and accessories.

	Treadle Pump (n=65)	Motor Pump (n=117)	Bucket (n=114)
Average capital costs of pumps	86.77	254.87	3.46
Average capital costs of accessories	48.50	137.04	0

4.6 Irrigation related challenges

Three main irrigation challenges identified in each location are presented in Table 4. For buckets and treadle pumps, the main challenge was the arduous nature of the technology. Farmers said that treadle pumps needed two people, one peddling and another irrigating. They also said it was tedious to peddle and also to carry the water hose in the field. Some quotations made by farmers were of particular interest for designers and promoters of treadle pumps:

"..Ina kazi nyingi. Inafaa sana wafungwa hii" (It is just too tedious. It should be sent to convicts in prisons to use as punishment) Young male motor pump previous user, Lukozi.

"..Hii pumpu bwana ni mbovu, yaani ina kazi nyingi. Siku hizi watoto wakiniona nikiitoa nje tu, haya, watoroka mmoja baada ya mwingine" (This pump is bad, it is tedious. Nowadays when my children see me taking it out {to irrigate}, they disappear one by one" Elderly male treadle pump user, Mabanda, Mbarali District.

It was generally observed that some farmers, especially younger ones, prefer using buckets to treadle pumps. They said that buckets were faster. For motor pumps, the issue of pump cost was a major challenge. For almost all respondents interviewed who were either practicing manual irrigation or those using treadle pumps, their preference was "*to get more money and buy motor pumps*". It was observed that the cost of motor pumps has dropped. However, that brought in the challenge of quality. Farmers, especially those knowledgeable of motor pumps, specifically in Kilimanjaro region, complained of low quality imports of motor pumps from China. *"They come in different brand names and they are cheap, but how long do they last.. 3 months, 1 year?"* One respondent said.

One challenge that cut across technologies was water scarcity, especially during the dry season. In drier parts like Dodoma, water sources were the largest limitation. This was particularly a problem with motor pump users as motor pumps need more water at a given time than buckets and treadle pumps. Intervention on water lifting devices may be constrained by development of water sources.

Table 9. Major irrigation challenges.

	Treadle Pump (n=65)	Motor Pump (n=117)	Manual Bucket (n=114)
Water scarcity (%)	11.5	49.3	24.3
Pump costs and quality (%)	2.1	48.3	n.a.
Tedious	86.4	2.36	77.7

5. Adoption of Water Lifting Devices

5.1 Ownership water lifting devices in Tanzania

Results from appraisal studies show buckets were the most widely used water lifting devices in Tanzania. The extensive use of buckets could be attributed to reasons including:

- buckets are not expensive and are easy to use and maintain;
- farmers have fragmented land holdings and buckets allow them to easily move between plots;
- can be used even when water levels are low; and
- can be used with other kinds of water lifting devices and even at different crop stages.

Table 10 shows the numbers of farmers who own different water lifting. The number of users of devices other than motor pumps is much higher since bucket farmers who often hire or borrow pumps for use (the discussion on this is on subsequent sections). In the four regions where rapid appraisal was conducted, an average of 2.25% owned treadle pumps and 6.15% owned motor pumps. These same farmers also owned buckets, which they could use at certain crop stages especially when seedlings were in the nursery or at early cropping stages.

Table 10. Proportions of farmers owning different types water lifting devices in Tanzania.

	Tanga (N=1832)	Morogoro (N=1350)	Dodoma (N=2100)	Dar es Salaam (N=550)
Treadle pumps	1.0	4.2	1.3	2.5
Small motorized pumps	4.2	4.7	10.3	5.4
Manual buckets/cans	94.8	94.0	88.6	92.1

A number of reasons could explain the proportions shown in Table 3. For example, high ownership of pumps in Dar es Salaam is limited by small plots available and insecure land tenure. The comparatively higher ownership proportions of farmers with motor pumps in Dodoma could be attributed to the agro-ecological zone. Dodoma is very dry and water sources are mainly rivers. Farmers therefore have few choices but to buy motor pumps if they want to irrigate their fields which are further from the rivers. Carrying buckets becomes much harder than if water sources are closer. This could also explain why treadle pumps in Dodoma do not have wide usage.

In general, from the rapid appraisal, it was clear that farmers had a strong preference for small motorized pumps. While motor pumps were found in almost every village visited, treadle pumps were concentrated in some areas. The distribution of pumps could be attributed to a number of factors including:

NGO support: World Vision International (WVI), an NGO actively working in Tanzania, is one of the major buyers of MoneyMaker pumps in Tanzania. It was common to see MoneyMaker pumps concentrated in most WVI supported communities like Bihawana in Dodoma Urban District.

District support: In Muungano village, Muheza District in Tanga Region, six PEP treadle pumps have been installed. The installation was done in such a way that farmers could share pumps to irrigate leafy vegetables (*mchicha*). This has been done even though many farmers in the community still had motor pumps. Funding was done by the Muheza District funds.

Water source restrictions: In Mabanda, Mbarali Districts, farmers were limited to using either buckets or treadle pumps as motor pumps will use too much water. This is also becoming common in many parts of Iringa Region, which is now implementing the new river basin restrictions that don't allow farming to be done some hundreds of meters along water bodies.

Droughts: Prolonged dry spells experienced in East Africa since 2007 pushed many farmers, even cereal farmers, to buying of pumps (mostly motor pumps but also treadle pumps for those who could not afford motor pumps) to save their crops. Farmers in Arumeru increasingly bought pumps in the previous year prior to this study to avert crop failures, which had been experienced in previous years.

Good marketing tactics: Kickstart International is well branded in Tanzania. In every regional capital and many big towns in Tanzania, there are MoneyMaker dealers and billboards. It is much easier to locate MoneyMaker pumps in Tanzania than even motor pumps. In some communities visited, there some farmers who were strong advocates of MoneyMaker pumps. This was observed in Kibaha, in Dar es Salaam where one female MoneyMaker owner has influenced many village farmers to buy their own MoneyMaker treadle pumps.

Other factors: Some unique location factors can also influence what water lifting device to use. For example, the stream that passes through Muungano village, Muheza District, which farmers use for irrigation and also for domestic purposes, is infested with crocodiles. Several cases had been reported in the village of crocodile attacks. This motivated people in the village, including domestic water users to use pumps. So in the village, farmers seldom irrigated using buckets for of fear of crocodiles. In some locations, water sources are large rivers that make it hard for manual irrigators to collect water, unless they dig dugouts and shallow wells near the large rivers.

5.2 Profile of current users of water lifting devices

5.2.1 The gender dimension

The proportion of females to males using motor pumps was significantly lower compared to buckets and treadle pumps (Table 11). On average, for every one female irrigator, there were 13, 3 and 2 males using motor pumps, buckets and treadle pumps respectively. This shows clear gender differences on technology use with a strong bias against motor pump use for women. This was clear in observations made in the field that most motor pumps were used by men. Treadle pumps had the lowest gender gap, even lower than buckets. This could be attributed to two reasons. First, manual irrigation is arduous since most vegetables have high water requirements. This becomes hard for most women especially as most manual methods like watering cans and buckets are carried as shoulder loads and hand loads (and not head loads) which are more favorable for men than women. Another reason could be the distribution of water lifting devices. Most NGOs involved in distribution of treadle pumps target individual women or women's groups in their poverty reduction strategies.

Table 11. Characteristics of users of water lifting devices

	Treadle Pump (n=65)	Motor Pump (n=117)	Manual Bucket (n=114)
Gender of respondents			
Male	69.58%	93.00%	76.84%
Female	30.42%	7.00%	23.16%
Mean age of respondents	36.6	39.8	39.6
Marital status			
Single	6.64%	22.00%	20.94%
Married	93.36%	76.00%	77.14%
Widow	0.00%	2.00%	1.94%
Educational level			
Informal	4.54%	2.00%	7.42%
Primary	82.36%	91.00%	84.08%
Secondary	13.10%	7.00%	7.40%
Tertiary	0.0%	0.0%	1.12%
Household size	5.28	5.12	5.14

While most users were married, more single farmers tended to use buckets and motor pumps compared to treadle pumps. Many young men preferred to use buckets than treadle pumps because they perceived treadle pumps to be tedious and much slower as compared to treadle pumps. Treadle pumps also needed two people and since they had no families, it was hard to get help in this highly competitive activity.

5.2.3 Education level and household sizes

Regardless of the technology, most farmers had up to primary school level education. However, buckets had significantly more farmers with no formal education than the pump-based technologies. Treadle and motor pumps need basic knowledge, so basic education and experience of use could just suffice for proper use. Most farmers learn informally from their friends how to use technologies but not from school. There were no significant differences between technologies by household size.

5.2.3 Socio-economic status

Assessment of the socio-economic status was done by an observation-based wealth ranking criteria which clustered variables into three major socio-economic indicators in farming communities. The indicators were: household assets (ownership of TV, radio, bicycle etc), farm assets (equipment such as pumps and other machines), and features of the houses (wall, roof and floor type). Food consumption and expenditure on clothing were not included as some respondents considered them too sensitive.

Rating was done on a scale of 1-5, with 1 showing lowest status and 5 the highest. Findings in Table 12 show households and farm assets owned by water lifting device had significantly more assets than the rainfed farmers. This was not however reflected in household features. Observations showed that household features were more linked to cultural and community-based factors than individual choices. For example, in Muungano, Muheza, farmers, even with those owning multiple pumps and large herds of livestock, were living in grass-thatch houses with mud walls and floors. This was not because the people had no money to build better structures but it was cultural for the people in the area to live like that. This could have never been the case in even the poorest farming household in Dar es Salaam.

Table 12. Socio-economic status of farming households

	Treadle Pump (n=65)	Motor Pump (n=117)	Bucket (n=114)	Rainfed farmers (39)
Household assets	2.35±0.4	2.50 ±0.8	2.25 ±0.65	1.68 ±0.7
Farm assets (equipment)	2.27±0.8	2.85±0.9	1.95±0.6	1.38±0.3
Residential House features	2.92±0.8	2.98±0.9	2.85±0.8	2.35±0.7

Comparison between users of water lifting devices show a general trend where motor pump users were ranked higher on wealth status followed by treadle pumps and buckets. Other than farm assets, there were no significant differences in other indicators (household assets and house features). Further data analysis show that deductions based on inter-community comparisons on water lifting devices is likely to be inaccurate due to wide differences in study locations. More accurate deductions can be made on intra-community comparisons of WLAT users.

Intra-community analysis on socio-economic status of WLAT users is shown in Table 13. It becomes now clearer that users of pumps had a higher wealth status than other farming households. Analysis showed that wealth ranking among owners of motor pumps (some users hired motor pumps and were not owners) had higher wealth ranking compared to other pump users. The question is whether farmers bought pumps because they were rich or pumps made them rich. While some econometric models could be used to analyze this using the survey questionnaire data collected, we added an extra question. This is better explained in the section on adoption dynamics.

Table 13. Intra-community comparison of socio-economic status of farming households

			Morogoro			Dodoma		
	Treadle Pump (n=17)	Motor Pump (n=23)	Bucket (n=53)	Rainfed (18)	Treadle Pump (n=18)	Motor Pump (n=13)	Bucket (n=23)	Rainfed (n=6)
Household assets	2.0±0.6	2.3 ±0.5	1.9 ±0.7	1.2 ±0.4	2.8 ±0.2	3.1 ±0.7	2.6 ±0.6	2.5±0.6
Farm assets (equipment)	2.2±0.8	2.5±0.5	1.4±0.6	1.5 ±0.5	3.0 ±0.5	3.6 ±0.8	2.5 ±0.6	1.0±0.0
Residential house features	2.8±0.2	3.1±0.9	2.9±0.9	2.6±0.5	3.1 ±0.3	3.3 ±0.8	2.8 ±0.8	2.3±0.5

5.3 Awareness on WLAT

Results from farmer surveys show high awareness levels of the various WLATs (Table 14). As expected, awareness levels were highest in Dar es Salaam, which is the capital city and where most large companies selling pump systems are based. Farmers in Dar es Salaam were urban and peri-urban farmers who were well exposed to shops and companies selling WLATs. Awareness levels on pumps were relatively lower in study locations in Arusha Region.

Table 14. Awareness levels of WLATs in study locations

	Motor Pumps	Treadle Pumps	Buckets
Morogoro	100	96	100
Dodoma	100	91	100
Tanga	98	93	100
Dar es Salaam	100	100	100
Kilimanjaro	88	94	100

5.4 Use of WLATs

Results from farmer surveyed show that buckets were the WLATs predominantly used by smallholder farmers (Table 15). High awareness levels did not lead to high usage rates. Dodoma had the highest number of motor pump users (10.3%) due the dry climate and hence high crop water requirements. The usage of motor pumps of other study locations was about 5% just like in the case of Tanga. However, the proportions given are of those who always use motor pumps. This proportion could be higher if we add the number of farmers who occasionally hire motor pumps for use. For example, in Dodoma, 26.6% of the farmers occasionally hire motor pumps, In Tanga, the proportion is even higher (69.1%). This is a clear indication of a developing motor pump market among irrigators. Usually there is a fixed fee for hiring a motor pump (either per day or area) and hiring farmers pay for fuel costs.

Table 15. Proportion of users of WLATs

Dodoma			Tanga		
Motor Pumps	Treadle Pumps	Buckets	Motor Pumps	Treadle Pumps	Buckets
10.3	1.3	88.4 (26.6)	4.2	1.0	94.8 (69.1)

5.5 Estimates on number of pumps in Tanzania

Information on estimates was obtained from supply chain dealers in the country. Based on Kickstart's database, monthly pump sales were generated since 2001 (Figure 4). The figure shows that between January 2001 and September 2009, a total of 38,549 (an average of about 370 pumps per month) MoneyMaker pumps were sold in Tanzania. About 89% of these are SMM pumps, with the rest being hip pumps. Even though hip pumps were introduced much later, their monthly sales have been much lower i.e. 90 pumps per month compared to 445 pumps per month for SMM pumps. The average monthly sales have generally been increasing over years i.e. from less than 100 pumps to about slightly over 600 pumps per month (see gradient line in Figure 4). Kickstart projects that this number will increase two-fold in the next few years since there demand has not been met in Tanzania.

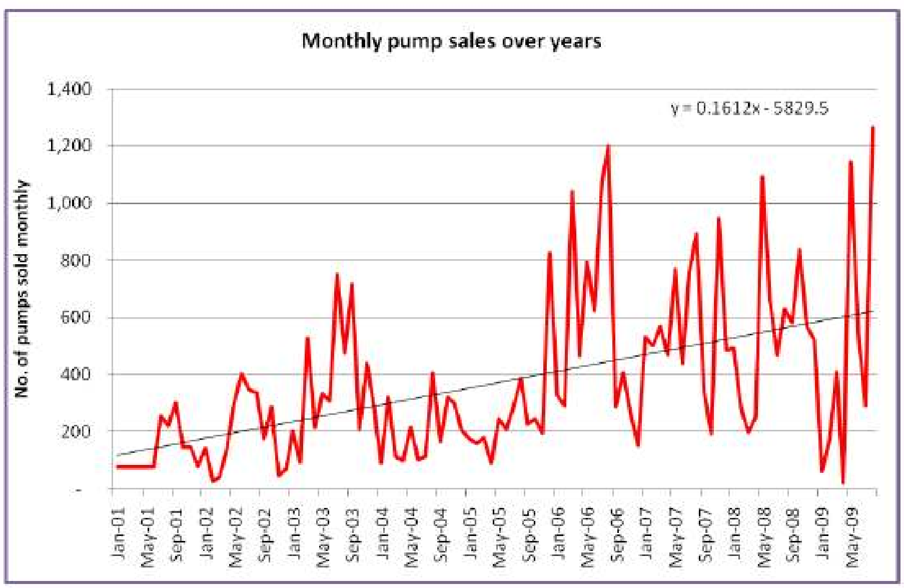

Figure 4. Monthly pump sales of MoneyMaker pumps

Estimates from W-3-W, the promoters of PEP show that since 2007 a total of about 1,200 pumps have been manufactured and installed in Tanzania. However, W-3-W doesn't have a monitoring database. In general, we estimate conservatively that there could be about 4,000 treadle pumps sold in Tanzania annually.

It was much harder to estimate the number of small motorized pumps used in irrigation in Tanzania for many reasons including the many numbers of dealers and the multiple purposes of pumps. Our surveys show two major entry points of motor pumps in Tanzania: By air – Arusha and Dar es Salaam, and by seas in Dar es Salaam. We assumed there are a few large and medium-scale importers in the country and they are mostly based in Dar es Salaam and few in Arusha and Mwanza. They then distribute to other medium- and small-scale dealers. Figure 5 shows the graphic we are developing to capture the distribution networks and quantify the numbers of small motorized pumps sold for irrigation in Tanzania.

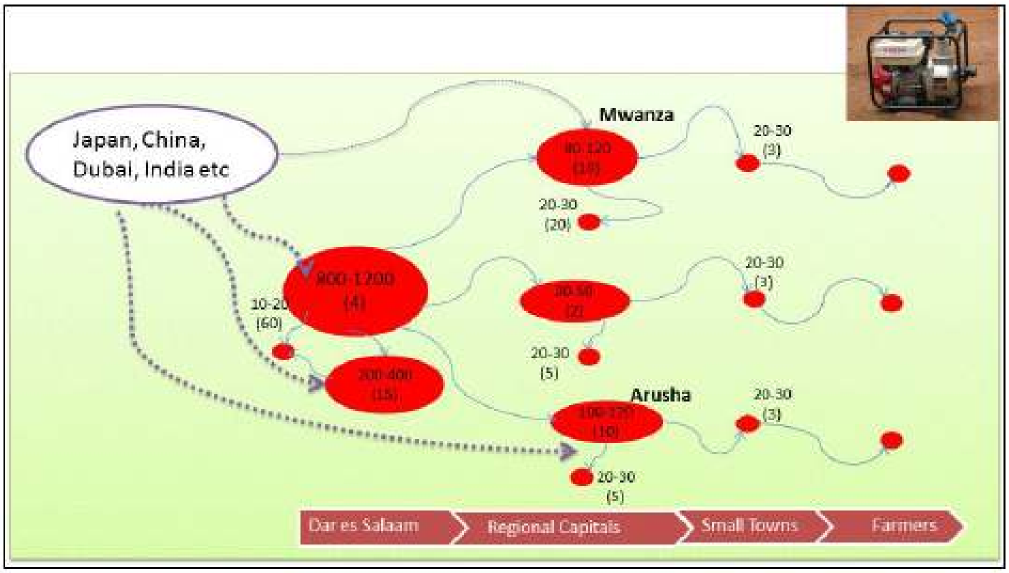

Figure 5: Supply chain of small motorized pumps and estimated numbers of pumps sold in Tanzania

From Figure 5, estimating all major dealers are importers and only half of the medium-scale dealers import, then the estimated number of pumps imported in Tanzania per year will be:

Through Dar es Salaam:

- Large importers: 1000 * 4 = 4000 pumps
- Medium importers: 300 * 15 / 2 = 2250 pumps

Through Arusha:

- 110* 10/2 = 550 pumps

Through Mwanza:

- 100*10/2 = 500 pumps

Hence, a total of 7,300 pumps per year.

Experts from major dealers estimated that the number could be 5,000-7,000, although few mentioned that it could be as high as 10,000 pumps. What was clear was that this number is increasing yearly. Taking a conservative estimate of 7,000 pumps yearly and a life cycle of 10 years, there could be 70,000 small motorized pumps used for irrigation by small-scale farmers in Tanzania.

5.6 Water lifting technologies ladder among smallholder irrigators

The adoption dynamics by smallholder irrigators observed in the field is conceptualized in the water lifting technology ladder shown in Figure 6. There was a general trend where farmers moved from purely rainfed systems to manual systems, treadle pumps and then to small motorized pumps. This is the conventional adoption pathway. Capital costs increase as farmers move up. For example, the average capital cost of manual systems was about USD 4.00 increasing to USD 135.00 for treadle pumps and up to about USD 400.00 for small motorized pumps. Though willingness to purchase motorized pumps was high, the ability was based on accumulating wealth from previous technologies lower in the technology ladder. However, there were exceptions.

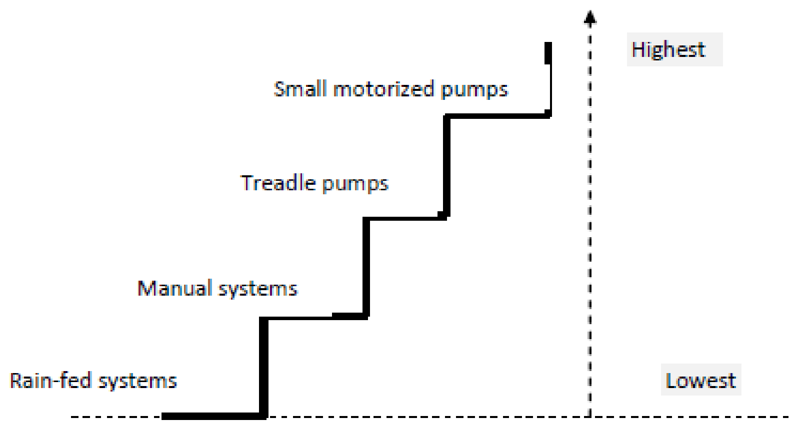

Figure 6. The smallholder irrigation water lifting technology ladder

Adoption of supported technologies: When there was external support, farmers could adopt the supported technology. This was particularly common for treadle pumps where NGOs like Kickstart International and World Vision Internal are actively supporting the adoption of these technologies. The government of Tanzania is also investing a lot in agriculture and some technologies like power tillers, drip irrigation are popular technologies. Farmers are prone to think, "Why not adopt free or subsidized technologies? This adoption of sometimes inappropriate technologies usually ends up being ineffective. The push marketing strategies employed may not be effective. In Muheza for example, one male farmer who had a PEP installed in his vegetable field said,

"they just gave us the pumps (PEP pumps) free. We didn't ask for them. We don't even like them. What we need are motor pumps" Male farmer, Muheza.

Looping in the ladder: It is increasingly common to bypass the treadle pump stage in locations where treadle pumps were earlier promoted. Farmers who used treadle pumps in early 2000 had negative perceptions about the technology and these negative perceptions put off new adopters. Our observations showed that treadle pumps are now selling better in new markets than in places where they were introduced first. Instead of buying treadle pumps, farmers in 'old' locations prefer to accumulate enough money to buy motor pumps. In addition, with the introduction of cheap Chinese motorized pumps, the gap in capital costs is reducing drastically. The Chinese pumps may not be so durable, but why buy a treadle pump at USD 85.00 when a motorized pump is USD 120.00?

Emergence of pump markets: There are some locations like Iukozi where more farmers are hiring pumps instead of buying them. While a high level of organization is needed in pump markets, this will certainly bring about changes.

Multiple technologies: Farmers using pump systems were still using manual systems. Among those using pump systems, there was a tendency to adopt more than one technology for various reasons. For example, farmers would keep treadle pumps and use them when they had no money to buy diesel. They could also use manual systems in nurseries or on some delicate crops.

5.6 Dis-adoption rates: Negative or positive dis-adoption?

Dis-adoption rates were highest for treadle pumps (Table 16). Treadle pumps are in the middle of the technology ladder (see section on technology ladder), so more prone to dis-adoption as farmers could move up or down. In this report, we distinguish between positive dis-adoption where farmers move upwards in the technology ladder, and negative dis-adoption where farmers move downwards. High dis-adoption rates among treadle pump users should not be seen as a failure of treadle pumps until further analysis is done to show if dis-adopters had an upward movement or a downward movement.

Table 16. Dis-adoption rates of WALTs in Dodoma and Tanga

	Dodoma			Tanga		
	Motor Pumps	Treadle Pumps	Buckets	Motor Pumps	Treadle Pumps	Buckets
Dis-adopters (%)	5	90.9	0	2	100	0
Positive dis-adopters	n.a	60.6	10.5*	n.a.	100	4.8*
Negative dis-adopters	100	30.3	n.a.	100	0	n.a.

Even on the upward movement, we need more analysis to ascertain the basis for the movement. If farmers made enough money when using treadle pumps and made an upward movement, then we can attribute upward movement to treadle pumps. As farmers continued using manual systems even if they had pumping systems, there was generally no dis-adoption for manual systems. Similarly, as motor pumps are seen to be the highest on the ladder, there was no positive dis-adoption. Negative dis-adoption of motor pumps was mostly attributed to low quality pumps and improper use while for treadle pumps, many farmers said that it was too labor intensive, did not supply enough water and there were maintenance problems. In general, low adoption of pumping systems was attributed to high capital and variable costs.

6. PRODUCTIVITY IN WLATs

6.1 Agricultural productivity of WLATs

Yields obtained from plots using various WLATs from this survey are shown in Table 17. This is based on the most grown vegetables in the respective study sites (in this case tomatoes) and maize for rainfed plots.

Table 17: Yields from irrigated and rainfed plots

	Irrigated (tons/ha)		Rainfed (tons/ha)	
	Motor Pump	Treadle Pump	Bucket	
Crop **Location**	Tomatoes	Tomatoes	Tomatoes	Maize
Morogoro	11.94 8.70-22.48	9.91 5.80-14.50	9.40 5.32-17.40	0.69 0.22-1.56
Dodoma	14.57 7.73-19.34	11.28 9.67-14.50	11.69 3.87- 18.37	0.78 0.44-1.33

Some deductions can be made from the Table 17.

Differences between WLATs: There are significant differences in productivity between the motor pumps and the two other assessed systems (treadle pumps and manual systems). The differences were more pronounced in Dodoma (about 3 tons/ha) than in Morogoro (2 tons/ha). This could be attributed to water scarcity which is more common in Dodoma, hence the greater impact that motor pumps can make compared. However, differences in yields between treadle pumps and buckets were not significantly different.

Differences between rainfed and irrigated plots: Maize is not usually irrigated and was not irrigated in the two study communities. Similarly, it is hard to grow tomatoes fully relying on rainfall. So, it was hard to compare productivity between rainfed and irrigated systems.

Variations in yields on same WLATs: The data shows wide variations in yields even with farmers who had access to the same kind of farming systems and WLATs. Farmers with low yields in irrigated plots could improve productivity for up to four times (see buckets Dodoma). The gaps were even more pronounced for rainfed systems with a potential of improving production for up to 4-7 times. In general, there was 2-4 times difference in yields between the same kinds of WLATs. This was attributed individual farmer practices in relation to water management, water availability and knowledge on using WLATs. This finding shows a great capacity to improve yields even within the same water lifting system.

Differences in locations: The findings also show differences in the study locations. Although Dodoma is drier, farmers there had significantly higher productivity on irrigated tomatoes than in Morogoro.

6.2 Revenues generated from farming activities

How much do farmers really make from these farming activities? Potential revenues (assuming all that was produced was sold) from our study areas are shown in Table 18. Yields and operational costs had more influence on potential revenues than market prices. The market price of the produce was not significantly influenced by the water lifting device as produce from different WLATs was sold in the same markets using measuring weights. The findings however show location differences in prices of products. For example, on average, farmers in Dodoma received 1.5 times higher prices for tomatoes than their counterparts in Morogoro. This could be attributed to scarcity of supplies of tomatoes resulting from water scarcity in Dodoma.

Table 18: Potential incomes generated by kinds of farmers in different WLATs

	Irrigated (US$/ha)						Rainfed (US$/ha)	
	Motor Pumps		Treadle Pumps		Buckets			
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Morogoro								
Expenditure	861.35	656.11-1144.45	737.02	635.43-831.78	655.23	320.28-1107.20	224.03	179.05-298.80
Revenue	1808.94	1297.28-2184.93	1584.17	912.37-2423.48	1504.38	334.54-3364.80	306.90	95.04-864.85
Profit (Loss)	947.59	152.82-1297.64	847.15	139.90-1591.70	790.12	(287.40)-2524.79	82.87	(131.53)-636.66
Dodoma								
Expenditure	1190.04	1039.72-1368.55	1175.31	1096.74-1215.54	1130.83	789.77-1573.84	166.42	123.55-193.88
Revenue	3464.83	2280.92-4561.85	2661.08	2280.92-3421.38	2810.14	950.38-5132.08	199.58	114.05-342.14
Profit (Loss)	2256.32	1178.48-3202.80	1485.77	1065.38-2207.74	1679.58	127.35-4075.25	35.16	(79.83)-155.86

Figures in parenthesis are negative values

Some deductions can be obtained from Table 18.

Comparison between irrigated and non-irrigated systems: Even though production variable costs were much higher in irrigated systems, they also had much higher revenues and profitability than rainfed systems. The differences are much more pronounced in the much drier Dodoma locations compared to the comparatively wetter Morogoro study locations. It may not be logical o argue to for a shift in crop production because the areas used for rainfed crops like Dodoma (millet and maize) are those further away from water resources. In Morogoro, most irrigated production is done during the dry season while rainfed production is done during the wet season, and at most times in the same plots.

Farm expenditure (variable costs): There were differences between WLATs and study locations. There were significant differences between the three assessed WLATs systems. In both locations. The variable costs were highest for small motorized pumps, decreasing to treadle pumps and buckets had the lowest. The farming activity with the greatest impact on variable costs was watering. These costs were for fueling motor pumps and labor to pump (treadle pump) or manually fetch water for irrigation (manual systems). The differences were more pronounced in Morogoro than in Dodoma. This is because in Dodoma, as water sources were further away; higher pay was given to hired labor for watering which closed the gap of fuel costs compared to Morogoro where hired labor was cheaper as water sources were further away while fuel costs were nearly similar in the whole country.

Potential revenues: There were significant differences between revenues from motor pump irrigated plots compared to the other two WLATs assessed. The differences were more pronounced in Dodoma than in Morogoro. For example, in Dodoma, farmers using motor pumps received about USD 800.00 and 650.00 per ha more than the farmers who used treadle pumps and manual systems respectively. As explained above, there were no significant differences in prices of farm produce from different WLATs. Hence, the differences in revenues received were due to the yield differences between the WLATs.

Potential profits: In Dodoma, there were significant differences in potential profits with farmers using motorized pumps getting the highest profits followed by those using buckets and then treadle pumps. However the difference in profits between motor pump users the other two systems was much more pronounced i.e. USD 771.00 and 577.00 for treadle pumps and manual systems respectively. This demonstrates the great potential that motor pumps have in drier climates than the other two systems for irrigating high crop water requirement crops like vegetables. In Morogoro, although WLATs had differences in profits, the differences were much less. In Morogoro, treadle pumps were more profitable than manual pumps, but as in Dodoma, motor pumps were the most profitable. Comparing locations, profitability in tomato production was about twice as profitable in

Dodoma than in Morogoro. Observations made in the two locations showed that in Morogoro, there was a tomato glut a while in Dodoma, every tomato produced was of value.

Actual incomes (based on what farmers actually sell) indicate that substantial amounts from rainfed plots are used for household consumption (Table 19). There was also a tendency among farmers to do barter trade for their produce. For example, farmers could exchange millet for maize, sorghum or beans. These kinds of transactions could not be captured in these calculations as farmers never perceived them as revenues. In most cases, all irrigated vegetables were sold. Only a few portions were kept for household use, but this proportion was always less than 1%.

Table 19: Actual incomes generated from various kinds of farmers in different seasons

	Irrigated (US$/ha)						Rainfed (US$/ha)	
	Motor Pumps		Treadle Pumps		Buckets			
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Morogoro								
Expenditure	861.35	656.11-1144.45	737.02	635.43-831.78	655.23	320.28-1107.20	224.03	179.05-298.80
Revenue	1789.69	1297.28-2184.93	1584.17	912.37-2423.48	1445.36	334.54-3326.35	306.90	0.00-285.12
Profit (Loss)	928.35	152.82-1297.64	847.15	139.90-1591.70	778.33	(287.40)-2524.79	(191.16)	(298.80)-96.94
Dodoma								
Expenditure	1190.04	1039.72-1368.55	1175.31	1096.74-1215.54	1130.83	789.77-1573.84	164.42	123.55-193.88
Revenue	3446.37	2280.92-4561.85	2661.08	2280.92-3421.38	2810.14	950.38-5132.08	85.53	0.00-171.05
Profit (Loss)	2233.75	1178.48-3202.80	1485.77	1065.38-2207.74	1679.58	127.35-4075.25	(78.88)	(193.88)-47.52

Figures in parenthesis are negative values

* Actual income is a factor of % yield sold. The more kept for household consumption, the less actual income.

7. TRIGGERS FOR CHANGE: WHERE TO INVEST?

7.1 Innovative capacity building

Farmer training was one of the seven priority intervention measures suggested by farmers in WLATs which could trigger changes in productivity in these systems. Traditionally, government agricultural extension officers have been responsible for training farmers at community level. A lot of investment is made to train extension officers. In Tanzania, there are agricultural research and training colleges in almost every region. The conventional training model so far has rather been top-down and it seems reliance on extension workers is a fallacy. Observations made during this study show that many extension officers are seen as visitors in the communities and the quality of their service was unsatisfactory based on assessments from farmers (Figure 7). Many vegetable farmers said that many extension officers are trained on crops like cereals and coffee but not the kind of vegetables that farmers plant. Farmers were particularly concerned about pests and pest control in vegetables.

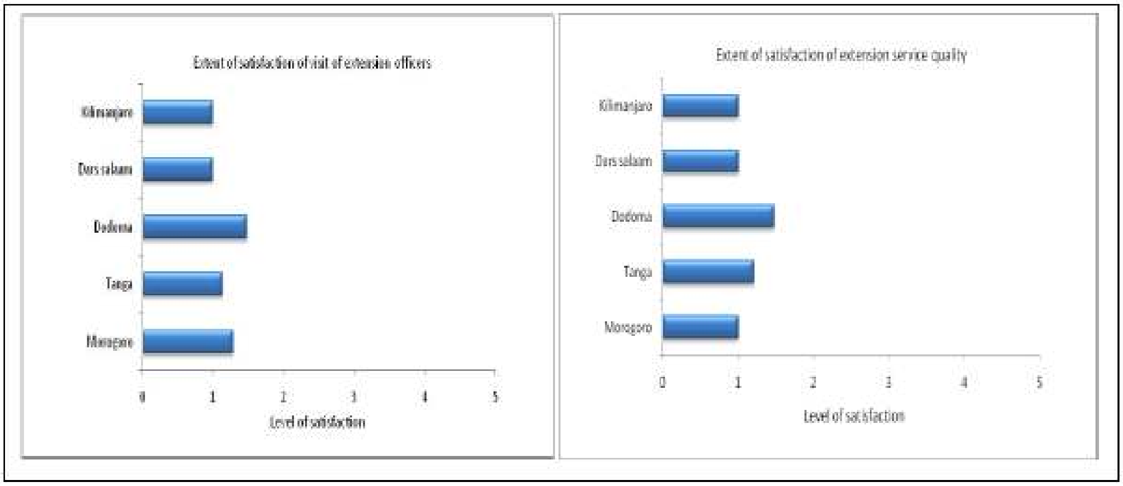

Figure 7: Level of satisfaction on extension services
#Ratings are on scale 1-5, based level of satisfaction of individual farmers

Observations made in the field showed that lack of access to appropriate and regular information and extension agricultural services is one of the greatest hindrances to AWM uptake among small-scale farmers in Tanzania. Some statements gathered from the field that reflect this include:

"*I now have irrigation water, thanks to MoneyMaker pumps, but two days ago, I applied pesticides on my vegetables and as you can see, they are now all burnt*" Mama Makundi (A farmer who used concentrated pesticides to spray her vegetable farm"

"…*Extension officers, I have never seen them, never in my 20 years of farming. I do farming as I know*" Juma, rural farmer in Tabora, Tanzania.

A particular concern for pump users was the knowhow of matching the capacity of pumps with plot size and crop water requirements. Farmers bought pumps that they found with the dealers. Many farmers could even not do basic repairs on pumps. One female farmer in Dar es Salaam said the treadle pump she was using had broken down and called the technology a bad one. Further investigation showed that it was only the seal that had worn off. Basic training for farmers on basic repair and maintenance of pumps will boost adoption and use of pumping systems.
" I first bought the this one (MoneyMaker Treadle Pump), my boys said that it makes them very tired. Then I bought this one (6HP Motor Pump), its diesel and was just too expensive. After that I decided to hire this one from a friend (3.5 HP motor pump), it broke down and I can't repair it. So I went and bought last week this one (hip pump), that is what the boy is now using" A farmer with 2 acres plot in Pwani Region.

From the survey of supply chain dealers, it was also clear that the know how among sellers, especially at regional and district levels, were also low. This means that training should extend to other actors in the supply chain. This observation was also made during the national experts stakeholder meeting for the AWM solutions project where capacity building was identified as a key trigger. In the meeting, participants said that capacity building should be for farmers, dealers and extension workers on the choice, use and maintenance of pumps. Participants went further to identify that this could be done during stakeholders workshops with practical demonstrations or tailor made courses for different actors.

Another aspect that farmers need good training on is marketing their produce and how to influence prices. Vegetables are perishable so timing of production and marketing is crucial. While weather conditions are a big limitation on production flexibility, choosing the right kind of crop, the acreage to plant, and timing are crucial to be competitive. Why grow tomatoes when all other farmers are doing the same while you can grow cabbage or green peppers which will make you more competitive? Satisfaction ratings for prices of farm produce by farmers was very low (Fig 8). In essence, every farmer complained of being "cheated by middlemen and traders". So why can't farmers devise ways to beat the system? Indeed, marketing was rated the third of seven priority intervention measures. Better marketing tactics like selling in groups/associations can give farmers a better bargain. This may mean that farmers create and/or strengthen farmer associations at community level. In some parts like Lukozi, Lushoto, farmer associations are very strong and instead of selling at communities, they transport their produce to Dar es Salaam and Zanzibar where they sell at higher prices.

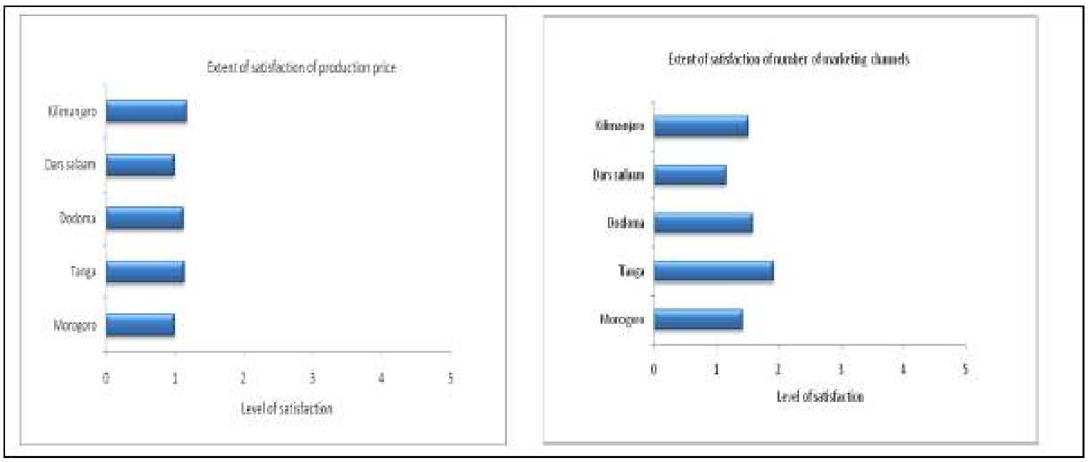

Figure 8: Level of satisfaction on extension services
#Ratings are on scale 1-5, based level of satisfaction of individual farmers

7.2 Credit facilities

The most highly prioritized intervention measures by farmers were related to subsidies and microcredit facilities (Figure 9) . Farmers complained of high costs of farm inputs especially for watering and pest control. They either needed subsidized inputs or flexible loans to buy inputs, farm equipment and hire labor to improve their productivity. Compared to the other five priority interventions under WLATs identified in different locations , subsidies, cheaper inputs and microcredit were of most concern in study locations in Tanga, Morogoro and Kilimanjaro. From our field assessment, while subsidies were good in the short-term, they tended to create a dependency syndrome which in the long-term results in negative impacts. They made farmers lazy instead of working hard to boost their own productivity.

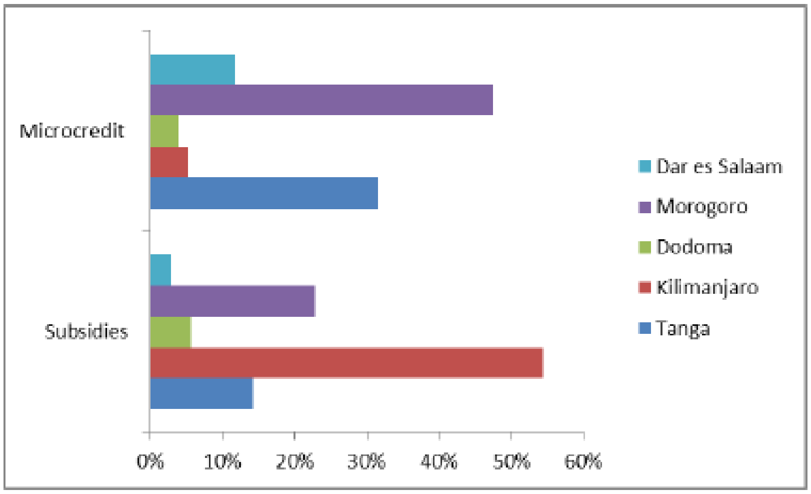

Figure 9: Ranking of subsidies and microcredit as priority interventions in different locations

The satisfaction levels on the quality of farm inputs, distances where they are bought, and their availability were generally good to very good (Figure 10). This is because in most agricultural communities there are dealers who sell the inputs farmers need. However, satisfaction levels of the price of inputs were very low, hence the clamor for cheaper or subsidized inputs and loans to buy the inputs.

"Farm inputs like seed, fertilizers and pesticides are too expensive. Sometimes the government and some NGO's subsidize fertilizers, but still we can't afford, they are still too expensive." Female farmer in Muheza, Tanga Region.

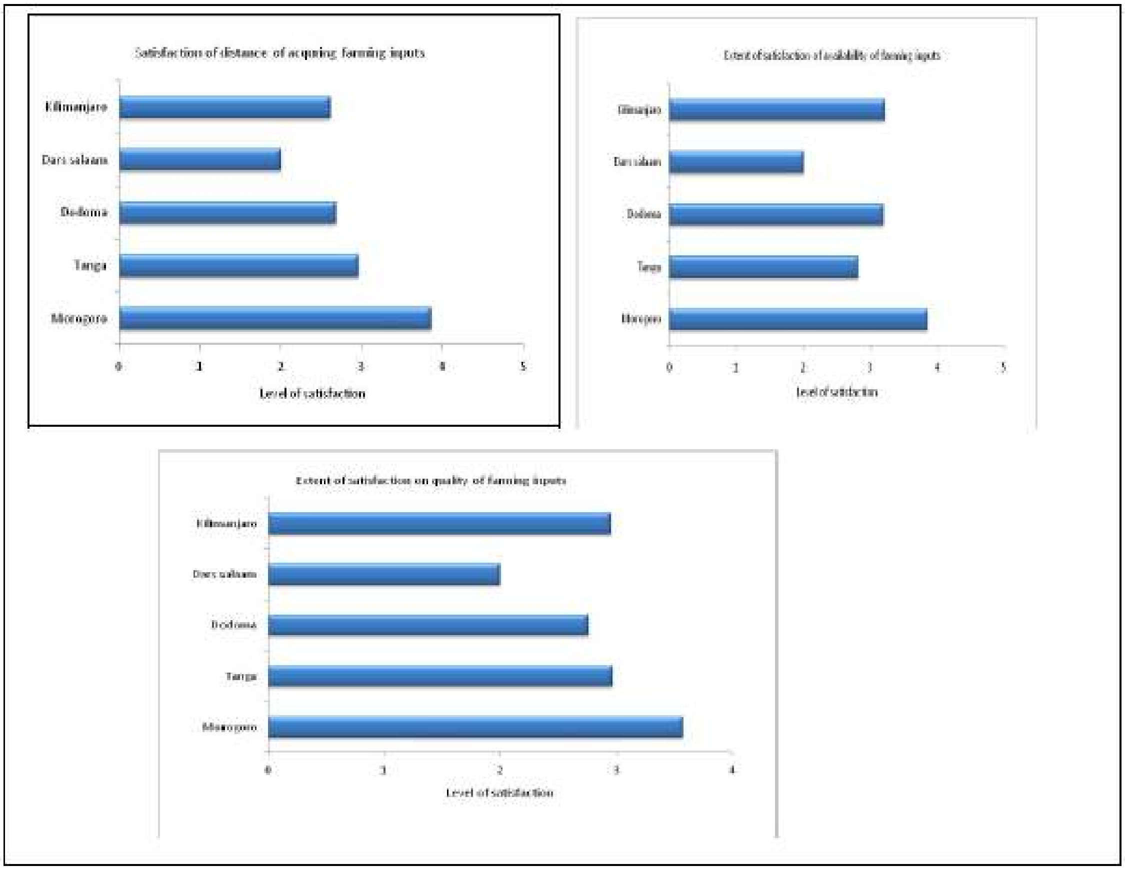

Figure 10: Level of satisfaction on distance, availability and quality of inputs
#Ratings are on scale 1-5, based level of satisfaction of individual farmers

How will farmers access microcredit facilities? In Tanzania, microcredit establishments, known as SACCOs (savings and credit cooperative organizations) are in almost every farming community. The problems that farmers have with SACCOs are the high interest rates and inflexible terms of repayment. Many farmers did not even bother applying for loans because they feared losing their assets like houses if they failed to repay. This was particularly common among women farmers, who seldom had ownership of collateral. Deeper assessment of the situation showed that the initial approach and flexibility of SACCOs has changed over time and now they operate more like banks. The misconceptions they had regarding crop failure and fixed repayments is fast fading away. Interviews with SACCO managers revealed they are now funded by banks hence the change in mode of operations.

As a way out, participants in the national experts’ forum for the project suggested credit assurance from the government to microfinance institutions involved in offering agricultural financial support services. They proposed that the assurance would enable SACCOs to offer loans at low interest rates as they were sure that the government will cover in case of crop failures. Other options could be for donor agencies to invest directly in well established SACCOs so farmers can benefit from flexible loans at low interest rates.

7.3 Improving access and availability of high quality pumps at local level

There are some locations in Tanzania which have been mapped out as potential areas for use of WLATs. A major trigger for change could be to ensure that high quality pumps are available and can be accessed. A main concern from the supply chain dealers was the quality of pumps. Many well established dealers complained that the influx of low quality pumps in Tanzania was “spoiling” the market with some farmers now saying that small motorized pumps were “bad” because they don’t last. This is a generalizations which could deter new adopters of pumps. Suggestions were given for creation of a registry of small motorized pumps for agricultural use accompanied by regular updating of the register. The register would capture information on the dealers, the kind of pumps, the quality and capacity.

Another emerging development which could be encouraged is the pump rental market. If economically and socially sensible, strengthening pump markets will ensure that more farmers have access to pumps by sharing without necessarily buying individual pumps. This can be done by dealers of farmers groups. Suggestions have been given for women’s’ groups to be involved in this, but in Tanzania, this may not be feasible because most farmers currently using pumps, even hiring for use, are men. A location like Lushoto where almost 70% of the current manual irrigators occasionally hire pumps could be a good starting test location for this intervention.

Another entry point is to improve access and availability in investments into research and development of low-cost pumping systems in Tanzania. In particular, experts in Tanzania advocated for integrated systems where, for example, water pumps can be incorporated on power tillers, which the government is aggressively promoting. There is also now a research department in the Ministry of Water and Irrigation which is leading efforts to improve pumping systems. This is also done in many universities, agricultural training institutions, and large pump dealers. Research should develop simple and clear guidelines for farmers on what capacity of pumps to buy for what plot sizes, crops, climatic zones, and basic repairs and maintenance. Other than research in specific technologies, research should extend to innovating marketing and promotion activities so as to increase access of pumps by farmers.

Care should be taken on the downside of increasing small motorized pump use in the country. What will happen if every farmer who wants a mortar pumps adopts one? Already, other users are complaining about extensive vegetable farming in Lukozi, Lushoto, where almost all available water is pumped out of the small streams. In principle, there will be no water left for other users. A careful balance is needed to optimize numbers and extent of use to avoid conflicts with the environment and with other users.

7.4 Improving water application systems

Even more critical in Tanzania will be investing in research and promotion of water application technologies like drip irrigation. The efficiency on the final delivery of water is poor. Farmers are using hose pipes to irrigate. Even better could be to use hose pipes with shower roses at the end, which could make the system more efficient. Thinking how to incorporate good and efficient water application systems with a water lifting device will be a positive step forward. For example, incorporating a good drip irrigation system will reduce the amount of water applied by half, so even time and fuel costs will be halved. There are now many low-cost drip irrigation kits which could be adapted for use in various parts of the country. In general, efficient use of available water will increase agricultural water productivity.

7.5. Developing water sources

There are some areas in Tanzania where the lack of water sources is a major hindrance to the use of WLATs. In drier parts like Dodoma, developing water sources is a priority intervention. Water harvesting technologies can be integrated so that the little available water can be stored for more efficient agricultural use. Closer water sources will reduce watering costs (fuel, manual labor) which will in turn increase returns.

“ ..*This is the river. When it rains, all the water from the mountains flows through at very high speeds, but there is nothing we can do. It flows like a train from Kigoma to Dar es Salaam. Our farms remain dry, our livestock remain thirsty”* Farmer standing on sandy river course in Bihawana, Dodoma.

Annex 1: Supply Chain Questionnaire

20th April 2010.

Dear esteemed pump dealer,

The International Water Management Institute (IWMI) is leading a three year research program funded by the Bill & Melinda Gates Foundation. Its objective is to identify investments in agricultural water management with greatest potential to improve incomes and food security for poor farmers and to develop tools and recommendations for various stakeholders in the sector including policy makers, investors, NGOs and small-scale farmers. This project is currently underway in 5 countries; Tanzania, Ghana, Burkina Faso, Ethiopia and India. The project has been introduced to the Directorate of Irrigation and other national stakeholders. In Tanzania, IWMI works in collaboration with the Soil and Water Management Program of the Sokoine University of Agriculture.

One of the most promising AWM solution identified is the use of small pumps for irrigation. As a dealer in pumps, I kindly request that you give us the information in the questionnaire attached to enable us achieve the goals of the project. Information given will be for research purposes only. Could there be any need for clarification, do not hesitate to contact me directly.

I count on your usual cooperation

Yours Sincerely,
Dr. Bernard Keraita
IWMI Africa Office
Current Location: SEI Africa Office, IRA, University of Dar es Salaam
Tel: 0653265155

Questionnaire No………………. Interview Date:…………………………. Interviewer ID:………………………

Dealer location:…………………………………………………………….
Dealer contact (Optional):……………………………………………………

1. How long have you been operating as a pump dealer?.
2. How many years have you been operating as a pump dealer in this location?..
3. What is your area of operation (how many districts/provinces or villages?
4. Who do you usually sell to? (farmers, other traders, …)
5. Where do your buyers come from?
6. What motivated you to start selling pumps?
7. Do the farmers approach you for technical guidance on the right brand/specification of pumps? If yes, how do you go about advising them?
8. Do you experience delays in supply of pumps after placing orders for them? Is the supply chain smooth?
9. If you repair pumps also, do you get adequate supply of spare parts?
10. Are you aware of any kind of restrictions (import restrictions, taxes, duties etc.) on pumps and their spare parts? If so, how does it affect your business?
11. Do you have suggestion that you can give to the government or investors to make your pump business better?

12. Please help us fill the table below to answer some more questions.

Type of pumps	Diesel pump	Petrol pump	Treadle pump	Electric pump	Other
Make/model range: Most sold					
Capacity (HP) range: Most sold:					
Where you buy from					
No. of suppliers you have					
Year started selling					
Are sales increasing or reducing over yrs					
No. sold last year					
Cost range Cost of most sold					
Do you sell accessories (Yes/No)					
Do you offer repair/maintenance?					
If yes, how many pumps did you do last year					

Thank you very much!