Assessment of Potential Markets for Soil Moisture Sensor in Tanzania

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3/17/2015

Executive Summary

SEED LLC is currently in development of low-cost soil moisture sensor to optimize irrigation and increase farm productivity in Africa. This soil moisture sensor prototype does not require calibration based on soil type, visually displays when "to" and when "not to" irrigate using LED signals, and has the capability to send data to the cloud real time as well as analyze in real-time. Our assessment analyzes the potential market for this soil moisture sensor in Tanzania by determining the need, desired design specifications, and commercial opportunity of this technology.

To determine the need for soil moisture sensor technology, we conducted extensive literature review on major forms of irrigation and high-value, water sensitive crops in Tanzania. Economic analysis on increases in crop productivity and subsequent increases in farmer revenue concludes that tobacco, highland rice, and maize are the three primary agricultural products that offer the greatest return and least risk on soil moisture sensor investments.

An evaluation matrix of the SEED soil moisture sensor prototypes with other currently available soil moisture sensor technologies was also conducted to compare design and performance capabilities. Our results show that the SEED sensor is highly competitive technology that meets or outperforms similar low-cost sensors. While total cost for the technology is estimated to range from $50 to $100 (including the sensor, a data logger, and a SIM card), SEED's soil moisture sensor is comparatively cheaper than other similar technologies but still provides the advantages that sophisticated technologies costing thousands of dollars bring. Cost of the soil moisture sensor can also be further reduced through analysis of the necessary, desired, and unnecessary features of the sensor according to stakeholders.

Finally, the commercial opportunity and potential channels for distribution were evaluated from stakeholder analysis. Using literature review and preliminary market research, four major channels for soil moisture sensor adoption were identified: 1) Non-governmental organizations (NGOs), 2) Financing institutions, 3) Private Agribusiness, and 4) Community-based or farmer organizations. Eighteen organizations, spanning from each channel, were initially contacted as preliminary market research. Based upon feedback and consultation with our client, key questions and an initial market survey questionnaire were developed.

This assessment concludes that tobacco, highland rice, and maize could significantly benefit from SEED soil moisture sensor adoption. While these three agricultural products are potential markets, analysis of the commercial opportunity show there are several social barriers and challenges that must also be addressed. As a next step, we propose a formal market survey of farmers and agricultural distribution organizations in Tanzania. Market survey of primary and secondary stakeholders, an extension of our preliminary research and developed questionnaire, would address these social barriers and further narrow the scope of potential stakeholders.

Table of Contents

1. Introduction

Seed LLC, founded by Mitesh Gala, is a social enterprise committed to improving the lives of rural farmers through the development of affordable and sustainable products and services. Previous technology products include a low-cost lightweight diesel irrigation pump designed to increase reliable water access for rural farmers in India. Currently, SEED LLC is in the development stage of a low-cost soil moisture sensor to optimize irrigation and increase farm productivity in Africa.

1.1 Problem Statement

We were tasked with assessment of the potential market for a soil moisture sensor to improve the lives of farmers in Africa, particularly Tanzania. Marketing of a soil moisture sensor in Tanzania requires in-depth analysis and understanding of the current market, geographical need, and potential customer. In order to determine this potential market, we strived to answer three key questions posed to us by our client:

1. Is there, and where is there, a need for soil moisture sensors?
2. What are the desired design specifications of a soil moisture sensor in Tanzania?
3. What is the commercial opportunity for this product?

2. Background

2.1 Soil Moisture Sensor Prototype

The soil moisture sensor prototype in development by SEED LLC uses proprietary technology to accurately collect and share soil-moisture data. The unique features of soil moisture device are that it does not require calibration based on soil type, it is easy to interpret, it visually displays when "to" and when "not to" irrigate using LED signals, and it has the capability to send data to the cloud real time as well as analyze in real-time. While the market retail price is not yet determined, estimated costs for a soil moisture sensor is $50-100 per sensor including the data logger and SIM card. The physical soil moisture sensor and communication board will be encased in durable PVC and can be installed and re-installed with ease. The design of this sensor combines an understanding of the physics of soil water measurement techniques and the social process of adaptive learning, particularly amongst smallholder farmers.

2.2 Agriculture in Tanzania

The predominant industry in Tanzania, illustrated in Figure 1, is agriculture with agricultural products accounting for approximately $6 billion or 85% of total exports (CIA 2015). In addition, Tanzania possesses significant potential for increased crop production. According to the World Bank in 2013, only one-third of arable land is currently cultivated in comparison to the more than 90% use of arable land in neighboring countries such as Malawi (Gaddis 2013). This national reliance on agriculture and the potential for future productivity improvement makes Tanzania as potential market for soil moisture sensor marketing and distribution.

Figure 1. Map of Tanzania provided by the FAO (2015). All major agricultural export products are distrusted through Dar es Salaam with a majority of commercial farms and established irrigation schemes located in Northern Tanzania (Mhelela 2012).

2.2.1 Agricultural Productivity

While the agricultural industry contributes significantly to the economy, it is primarily composed of smallholders and small-scale farming production, lowering overall production productivity. Average small-scale farm sizes ranges from 0.9 hectares to 3.0 hectares per household (TanzaniaInvest 2014). According to the Food and Agriculture Organization of the United Nations (FAO), major agricultural products in 2012 were bananas, beans, maize, cassava, and rice. Annual production of bananas alone was estimated at 250,000 MT (FAO 2015). In 2007, an estimated 49.6% of those living below the poverty line made their salary from the sale these food crops (Cleaver et al. 2010).

Subsistence farmers, according to research conducted by Sokoine University, are also more likely to maximize self-sufficiency over profit. As a result, small-scale farmers have adopted few technology and land management practice improvements in the past decade. Average food crop productivity in Tanzania is estimated at 1.7tonnes per hectare (ha), while good land management practice can increase yield productivity values as high as 4.0tonnes per ha (FAO 2015).

2.2.2 Irrigation

Water conservation is becoming crucial in Tanzania due to an increase in water demand from a growing population and economic growth. Currently, crops still fall well below potential yields due to poor water and nutrient application that cannot meet the demands of the crops

(Stirzaker et al. 2013). The FAO estimates that Tanzania has attained less than 20 percent of its irrigation potential. According to the International Water Management Institute, of the 5.1 million ha of cultivated farmland as few as 300,000ha are irrigated consistently (AWM-solutions 2015).

Existing types of irrigation systems currently in use in Tanzania are surface irrigation, conventional sprinkler irrigation, and drip irrigation. Method of irrigation varies according to crop type and income level. For example, surface irrigation is the most predominant form of irrigation while conventional sprinkler and drip irrigation are used rarely and only for large-scale commercial farming such as coffee (ICID 2014). Within the Kilimanjaro Region, traditional irrigation is primarily hill furrow systems dating back hundreds of years (Tagseth 2010).

Due to population increases and concerns of water scarcity, new water management policies and systems are being implemented to increase reliable water access. Increased irrigation for small-scale farming increases productivity and facilitates the transition from subsistence farming to commercial farming (Mdee 2014). The New Partnership for African Development (NEPAD) argues that the irrigation area needs to expand by 6 per cent per year, six times the current rate of increase, and governments of Tanzania and the donor community are now looking at serious new investments in irrigation infrastructure (Stirzaker et al. 2013). Introduction of a soil moisture sensor that improves the efficiency of water-use will not only help farmers make their activities more profitable, but also increase the sustainability of agriculture in general.

2.2.3 Product Distribution

The general distribution channel for agricultural products can be classified into four major levels, which are: 1) importers/national distributors, 2) regional/district distributors, 3) retailers such as convenience stores and kiosks, and 4) vendors including village markets and street hawkers. Descriptions of these players are as follows:

Importers or National Distributors

Distributers are involved in the ordering and purchasing goods in large quantities and subsequent selling of goods wholesale to the Regional/District Distributors. Almost all national distributors are located in Dar es Salaam, with some located in Arusha or Mwanza. International products are primarily imported from China and Germany and transport them by sea. Dar es Salaam is one of the key maritime ports in East Africa, handling the large majority of international exports from Tanzania (Feng 2014).

The challenges that face this level of the supply chain include: (a) Delay in clearing of the goods at the ports or airports due to bureaucracy and corruption, (b) High cost involved in transportation of goods to reach their regional and district agents due to poor transport infrastructure, (c) Damaged products due to improper handling of the goods during transportation, loading and off-loading, and (d) Lack of large warehouses for the storage of goods. A study by the Africa Center of the Atlantic Council concluded that transport costs are 63 percent higher in Africa compared to other developing regions (Feng 2014).

Regional or District Distributors

Regional distributors are located in the capitols of the regions or districts. These players are responsible for ordering the products from importers and selling them to the retailers. Some act as agents of the national distributors but others operate independently. In most cases they themselves travel from their regions to Dar es Salaam, Arusha or Mwanza to purchase their goods. Most use road or rail transport for transportation of purchased goods depending on the cost and location of the region. Regional distributors deal multiple goods. The challenges also face this category of intermediaries are similar to national distributors (Greenmax Capital Advisors, 2013)

Retailers (including convenience stores and kiosks)

Retailers are located in the regions, districts or in economic centers. They either sell their products to vendors or directly to end customers. The disadvantage for the retailers is that they are not able to vigorously promote the products or even engage customers in dialogue at potential points of sale. The retailers are generally faced with the following challenges: (a) There are less trained artisans/technicians to maintain, repair and service of the technology products (b) Absence of regional/district wholesalers in their local areas. The retailers are forced to travel to Dar es Salaam, Mwanza, or Arusha to buy goods c) Length of time between ordering and delivery of products (Greenmax Capital Advisors, 2013).

Vendors (Village Markets or Street Hawkers)

Vendors are split in two categories; those who sells their goods at the village markets, and street hawkers who move with few items along the road. They all keep their goods at their home, or at other retail shops, as they normally don't have an established place of business. Some of them buy a few items to sell while the rest enter into an agreement with a retailer for a commission. These are informal operators and normally pay only city taxes. They sell a wide range of products and modern technologies. Their advantage is that they know the consumers well in terms of location, purchase habits and purchase abilities; many of their customers are also neighborhoods, relatives, etc. They are often skilled at persuading their customers to purchase their goods (Greenmax Capital Advisors, 2013).

2.2.4 Factors Influencing Technology Adoption

The main factors affecting technology adoption among farmers in Sub-Saharan Africa are assets, vulnerability, access to information and government regulations. While these factors are not all fully taken into consideration and analyzed in the scope of this assessment, further research and market studies should be conducted as a future step.

Assets

Assets are both requisite physical material and abstract possessions (e.g. education), which are essential to technology adoption (Meinzen-Dick et al., 2004). Ownership of land is often thought to be a prerequisite for obtaining financial credit. For example, in Ethiopia, farmers must have at least 0.5 ha under maize in order to participate in a credit scheme for maize. In Kenya, the Seasonal Credit Scheme requires that farmers have at least 5 acres of land. Thus, farmers with smaller amounts of land will not have access to formal credit, limiting potential to invest in soil moisture sensors (Muzari et al, 2012).

Vulnerability

Vulnerability factors deal with the impact of technologies on the level exposure of farmers to economic, biophysical, and social risks (Meinzen-Dick et al., 2004). Technologies that possess a lower risk have a greater appeal to smallholders who are naturally risk-averse (Meinzen-Dick et al., 2004). It has been conceded that traditional smallholder farmers have their rational reasons for not adopting untried technologies (Mazonde, 1993). Because a majority of small-scale farmers in Tanzania are subsistence farmers, measures must be implemented along with proper marketing to increase their willingness to adopt new technologies such as the soil moisture sensor.

Access to information

Another variable important to technology adoption is access to information. Farmers must have information about new technologies before they can consider adopting them. Also, knowledge about the benefits received by the user and the costs of the product is an important determinant of new technology adoption (Hall, 2002).

Government and regulations

Private and government regulatory institutions have powerful influence on technology adoption, often via sponsorship. To protect farmers from the growing stresses of extreme weather and climate change, Tanzania's parliament in 2013 has passed a new law to promote better use of irrigation in order to improve food security and reduce poverty. The Minister for Agriculture, Food Security and Co-operatives Christopher Chiza explains that the new law will pave the way for the country to use its available land resources for the sustainable development of irrigation (Makoye, 2013).

This law, among other things, establishes the Irrigation Commission, a national body with the mandate to co-ordinate, promote and regulate irrigation activities across the country. The legislation also establishes the formation of an Irrigation Development Fund to help irrigation schemes, which are often lacking financial backing. The fund's monies — to include both government and non-government sources — will be used to finance irrigation activities carried out by individual farmers and investors, through loans or grants. According to Minister Chiza, the government is now implementing 39 irrigation schemes on 16,710 hectares, using drip irrigation technology at a cost of Tsh677.5 billion ($400 million). Once the Irrigation Commission is fully established, the Commission plans to further implement more than 1,000 new schemes, depending on the availability of funds (Makoye, 2013).

3. Methodology

To analyze the economic drivers and future investments of a potential soil moisture sensor in Tanzania, we focused on three areas: the need for soil moisture sensor, desired design specifications and commercial opportunity. Each key area was initially approached individually. The results of each key sector were compiled and evaluated, narrowing the scope and creating an iterative process. Final market analysis resulted in the formation of a preliminary market research study.

3.1 Need For Soil Moisture Sensor

Determination of the need for a soil moisture sensor is based upon analysis of key agricultural products in Tanzania. Key crops for analysis are selected from literature review of major subsistence and high-value export crops. For each agricultural product selected, an economic scenario analysis and study of crop requirements were conducting using information provided by the FAO. In addition, potential social barriers and challenges were briefly touched upon.

3.1.1 Crop Selection

As mentioned above in Background, major agricultural products are bananas, beans, maize, cassava, and rice. While major agricultural products are subsistence foods, agricultural exporters possess access to more established market pathways and capital to invest towards increased productivity. Based on data provided by the MIT Observatory of Economic Complexity, major agricultural export products are detailed in Table 1 (Smoes 2015).

Table 1. 2011 gross export value of the top five largest agricultural exports from Tanzania.

Agricultural Export	Gross Value (100 millions)
Raw Tobacco	328
Coffee	188
Nuts and Cashews	182
Raw Cotton	155
Oily Seeds	118

Table 2. Five main agricultural products selected for evaluation. For each product, potential increase in productivity and farmer revenue due to implementation of a soil moisture sensor is studied.

<table>
<tr><th>Type of Farm</th><th>Crop</th><th>Type of Irrigation</th></tr>
<tr><td rowspan="2">Subsistence</td><td>Highland Rice</td><td>Rainfall/ Canal Irrigation</td></tr>
<tr><td>Maize</td><td>75% rainfall/ 25% Irrigated</td></tr>
<tr><td rowspan="3">Commercial</td><td>Tobacco</td><td>70% rainfall/ 30% irrigated</td></tr>
<tr><td>Coffee</td><td>rainfall</td></tr>
<tr><td>Cotton</td><td>Drip</td></tr>
</table>

As a result, a selection of subsistence and high-value export crops are analyzed as a potential market for soil moisture sensors. Based on data availability and literature review, the key crops analyzed for this project are listed in Table 2. While nuts and cashews are high value export products, they are not selected due to current political turmoil and unrest amongst cashew farmers (Ghosh 2013).

3.1.2 Sensitivity Analysis

Proper farmland management, including irrigation and nutrient addition, has the potential to increase crop productivity and yield significantly. According to the World Bank, development of irrigation schemes in highland regions has the potential to more than double both crop yield (average 1.5 tons per ha to 5.0 tons per ha) and area of cultivated farmland (World Bank 2013). Studies on the benefits of soil moisture sensors conclude that crop yield can increase as much as 50 percent for water-sensitive crops in extremely dry seasons (Roberson 2010).

To model sensitivity and potential variations in irrigation schemes and yield, five different scenarios were chosen ranging from the worst-case scenario (Scenario 1) to best-case scenario (Scenario 5). These scenarios are described below in Table 3. For each scenario, it is assumed that one soil moisture sensor, priced at $100, is purchased.

Table 3. Five main agricultural products selected for evaluation. For each product, potential increase in productivity and farmer revenue due to implementation of a soil moisture sensor is studied.

Scenarios	Irrigation	% Increase in yield
1	Already established irrigation system	10
2	Already established irrigation system	20
3	Installation of irrigation system	30
4	Installation of irrigation system	50
5	Installation of irrigation system	100

Using the results from each scenario, the payback time (years) required to pay the cost of a soil moisture sensor (Scenarios 1 and 2) or soil moisture sensor/irrigation system package (Scenarios 3 – 5) is calculated. The cost of new irrigation system is based on data collected by the FAO for maize and estimated at $90/ha with additional operating costs of $16/year (FAO 1997). Interest rates of loans are also ignored but should be taken into account during more in-depth analysis. Typical discount rates offered by the Central Bank of Tanzania were 8.25 percent in 2010 (Mecometer 2010). Thus, we assume discount rates will vary between 10 to 20 percent for rural farmers. Also, additional subsidies should be taken into account, specifically the support and encouragement of the Tanzanian government for farmers to adopt irrigation systems.

3.2 Desired Design Specifications

Evaluation of desired design specifications is conducted via two processes: 1) evaluation matrix of current soil moisture sensors on the market, and 2) analysis of required performance capabilities for selected crops. The evaluation matrix of current soil moisture sensors compares cost, accuracy, technical skill level, labor intensity, durability, and lifespan. Accuracy, technical skill level, and labor intensity were scaled from 0 to 5, with 0 as least desirable and 5 as most desirable. Valuation and weightage of each criterion is not conducted and should be determined through a market survey of primary stakeholders, which is further discussed in Section 5.1 Future Work.

3.3 Commercial Opportunity

The commercial opportunity for a soil moisture sensor, in addition to its technical capabilities, is also influenced by the product's accessibility to channels for advertising and distribution. Literature review as well as contacting of potential stakeholders allowed for the identification of possible channels and challenges for implementation. From this, stakeholder analysis was conducted comparing the interest and influence of both types of stakeholders.

3.4 Preliminary Market Research

Based upon potential markets identified via literature review and preliminary economic analysis, preliminary market research is needed to further narrow the scope and identify potential challenges and social barriers. Prior to implementing a formal market survey, several NGOs, microfinance institutes, and distribution companies were contacted to discuss the need and opportunity for a soil moisture sensor in Tanzania. Table 4 below lists the organizations identified as potential stakeholders or resources. All organizations were contacted via email, phone, or Skype. Initial feedback from select organizations helped design the development of a formal market survey, which will be discussed in Section 5.1 Future Work.

Table 4. Various types of organizations based in the United States and Tanzania that were contacted for preliminary market research on the viability of a soil moisture sensor in Tanzania.

Type	Country	Organization
NGO	USA	ECHO East Africa Impact Center
	USA	Mercy Corps
	USA	Skoll Foundation
	USA	RSF Social Finance
	Kenya	One Acre Fund
	Bangledesh	BRAC
USAID	USA	Feed the Future
	USA	Tanzania Agriculture Productivity Project TAPP
Agricultural Distribution	Tanzania	IRRICO
	Tanzania	BALTON
	Tanzania	Ongeza
Microfinance	Tanzania	PRIDE
	Tanzania	FINCA
	Tanzania	National Microfinance Bank (NMB)
	Tanzania	YOSEFO
	Tanzania	TAMFI
	Tanzania	Tujijenge
Farming Collective	Tanzania	Tanganyika Planting Company (TPC)

4. Results

4.1 Need For Soil Moisture Sensor

For the five identified potential crops (tobacco, highland rice, maize, cotton, and coffee), the average farm size, type of irrigation, farm gate price, and yield (based on current irrigation practices) are estimated using data provided by the FAO (2015). This information is summarized in Table 5. In Table 5, 'Potential Yield' is defined as the maximum theoretical yield per crop and 'Increase in Revenue' is the difference between current farmer revenue and maximum potential revenue per crop.

While this assessment does not assume a soil moisture sensor implementation can achieve maximum potential yield, it is important to recognize the maximum increased profit that can be made per crop. Illustrated in Table 5, tobacco, rice, and maize possess the highest potential benefit from soil moisture sensor use. While all five crops' increase in revenue exceeds $100 per harvest (price of one soil moisture sensor), this only pertains to the best-case scenario.

Table 5. Average and potential productivity and revenue for the five potential crops in Tanzania. The increase in revenue column is indicative of the potential benefit and increase in profit a soil moisture sensor can have.

Crop	Farm Size (ha)	Type of Irrigation	Yield (tons/ha)	Potential Yield (tons/ha)	Farm Gate Price $US/kg	Revenue $US/ha	Potential Revenue $US/ha	Increase in Revenue $US/ha
Tobacco	1.3	Rainfall/ Canal Irrigation	1.20	2.50	0.82	1276	2659	1382
Rice	1.3	75% rainfall/ 25% Irrigated	1.80	3.84	0.44	983	2098	1114
Maize	2.1	70% rainfall/ 30% irrigated	1.20	2.00	0.15	378	630	252
Cotton	1.9	rainfall	0.55	0.90	0.26	271	443	172
Coffee	0.9	Drip	0.23	0.40	0.82	166	294	129

4.1.1 Sensitivity Analysis

Sensitivity analysis of the effect of soil moisture sensors on increases in crop yield is conducted for five different scenarios detailed in Section 3.1.2. Scenarios 1 and 2 assumes the farm already possesses access to an established irrigation system, while Scenarios 3 – 5 assume the implementation of an irrigation system with the soil moisture sensor. Table 6 illustrates the potential increase in revenue for each of the five selected scenarios.

Using the results from each scenario, Table 7 details the payback time required to pay off the capital equipment costs (soil moisture sensor for Scenarios 1 and 2, and combined irrigation system/soil moisture sensor for scenarios 3-5). From Table 7, Tobacco and Rice offer the lowest risk to small-scale farmers as the soil moisture sensor is repaid within one to two years. Coffee and cotton are significantly riskier investments as multiple harvests are required to repay the cost of the sensor. Factoring in potential droughts and other unexpected factors that may decrease productivity, full return on the soil moisture sensor may not be attained within the sensor's five year expected life span for cotton and coffee.

Table 6. Potential increase in revenue per year for five different scenarios. Scenarios range from established irrigation and 10% increase in yield (Scenario 1) to installation of both irrigation and soil moisture sensor resulting in 100% increase in yield (Scenario 5).

Crop	Farm Size (ha)	Yield (tons/ha)	Farm Gate Price $US/kg	Revenue $US/ha	Scenario 1 Increase in Revenue $US/ha	Scenario 2 Increase in Revenue $US/ha	Scenario 3 Increase in Revenue $US/ha	Scenario 4 Increase in Revenue $US/ha	Scenario 5 Increase in Revenue $US/ha
Tobacco	1.3	1.20	0.82	1276	128	255	383	638	1276
Rice	1.3	1.80	0.44	983	98	197	295	492	983
Maize	2.1	1.20	0.15	378	38	76	113	189	378
Cotton	1.9	0.55	0.26	271	27	54	81	135	271
Coffee	0.9	0.23	0.82	166	17	33	50	83	166

Table 7. Payback time of capital equipment costs in years for each of the five scenarios. A 10 to 20 percent interest rate on capital equipment is excluded for this analysis.

Crop	Scenario 1 Payback time (years)	Scenario 2 Payback time (years)	Scenario 3 Payback time (years)	Scenario 4 Payback time (years)	Scenario 5 Payback time (years)
Tobacco	1	1	1	1	1
Rice	2	1	1	1	1
Maize	3	2	1	1	1
Cotton	4	2	1	1	1
Coffee	Never	4	2	1	1

4.1.2 Crop Requirements

While economic analysis identifies crops that result in the highest potential monetary gain, the model does not consider the variations in expected average yield increases for each crop. In order to maximize agricultural productivity, soil moisture sensor should also be marketed towards crops that possess high water sensitivity and large variability in water needs.

The crop coefficient, Kc, is a coefficient that predicts the potential evapotranspiration of different crops (FAO 1998). As Kc increases, the expected plant evapotranspiration increases, resulting in larger required water application. The crop coefficient also varies significantly depending on the crop's stage of growth (FAO 1998). Thus, a large range of Kc values during a plant's lifetime correlates to changing water needs. Soil moisture sensors should be marketed towards crops with significant variations in crop coefficients due to the sensors ability to maximize water use.

Table 8 below details the range of Kc values for each major cash crop and staple crop in Tanzania. In addition to crop coefficients, each crop is also classified according to water sensitivity and average root depth during its lifetime. Based on the data present in Table 8, Tobacco is a highly water-sensitive crop that requires varying levels of water during its growth. The relatively shallow root depth, 0.25m – 0.8m also allows soil moisture sensors to be more easily placed and removed. In comparison, cotton and coffee are relatively stable crops with deep roots resulting in increased installation costs for a smaller potential increase in yield.

Table 8. Comparison of various crops according to rate of evapotranspiration, water sensitivity, and root depth. Values shown below are based on information provided by the FAO (1998).

Crop	Kc Range	Water Sensitivity	Root Depth (m)
Tobacco	0.5-1.15	high	0.25 - 0.8
rice	0.6-1.20	high	0.5 - 1.0
maize	0.15-1.15	medium-high	1.0 - 1.7
Cotton	1.15-0.40	low	1.0 - 1.7
Coffee	0.9-0.95	medium-high	0.9 - 1.5

4.1.4 Social Barriers

Although economic analysis identifies potential crops of interest as tobacco, highland rice, maize, cotton, and coffee, results do not incorporate potential social barriers to adoption.

Raw Tobacco

Tobacco is the most exported agricultural commodity. Three main types of tobacco are grown in Tanzania: flue-cured, fire-cured, and air-cured burley tobacco (Mangora 2012). According to the University of Georgia, tobacco is a drought-resistant crop that is sensitive to water application. In addition, due to its nutrient requirement, tobacco is rarely grown for two consecutive seasons on the same land. Instead, a four-year crop cycle of tobacco with staple crops such as maize or beans is used (Mangora 2012). When tobacco is not being cultivated, soil moisture sensors could be removed and re-used for other crops or in other fields.

Potential constraints of the tobacco industry as a likely market are increasing concerns over environmental impacts. Approved commercial production of tobacco in Serengeti by Ministry of Agriculture, Food Security and Cooperative has resulted in significantly increased deforestation (Jacob 2013). Many NGOs and environmental advocacy organizations are currently lobbying to limit the expanse and size of tobacco farms, limiting tobacco market growth. In addition, our client has raised concern over the ethical promotion of the tobacco industry.

Raw Cotton

90% of cotton is produced in the regions south of Lake Victoria with average farm sizes ranging from 0.5 to 10 hectares (Baffes 2002). Smallholders comprise a majority of cotton farmers since the Cotton Act of 1994 and subsequent elimination of the monopoly held by the Cotton Board. While the cotton reformation yielded improved small-scale farming, lack of unified oversight resulted in decreased cotton quality (Baffes 2002). Lack of established irrigation systems, unstable cotton cooperatives and low-quality seeds minimize the potential benefits of soil moisture sensors.

Coffee

Tanzanian coffee is grown primarily in the Northern regions of Mount Kilimanjaro and Mount Meru, the Southern highlands of Mbeya and Ruvuma, in addition to the Western areas along Lake Victoria. There are many established institutions designed to increase national coffee production and quality through cooperation (Kumburu 2013). These institutions include the Tanzania Coffee Board (TCB), Tanzania Coffee Development Trust Fund (TCDF), and Tanganyika Coffee Growers Association (TCGA) (TCB 2010). These associations can serve as resources for sensor marketing and distribution. Although coffee production is expected to increase in Tanzania, increasing population has decreased the average smallholder farm size to 0.6ha in the Kilimanjaro region. This is more than half the farm size of other average smallholder cash crop fields such as cotton (1.25ha) (Maghimbi). Small farm size decreases total revenue and reduces farmer willingness to invest in new technology.

4.2 Desired Design Specifications

As shown in the Table 9, there is a wide range of available technologies for measuring and monitoring soil moisture or soil water content.

Table 9. Comparison of current soil moisture sensor technologies available on the market to SEED soil moisture sensor prototype. Table is adapted from information gathered from Sanden et al. (2003).

Types	Cost	Accuracy	Lifespan (years)	Durability	Technical skills required	Data Collection
Steel rod depth probe	$3	Low accuracy (no data)	Long lifespan (steel)	High	Quick and easy to determine depth of wetting. "Hand-feel" technique to measure moisture and compared with chart.	Manual Readings
Tensiometer	$50	Accurate	10	High	Easy to install, needs calibration, interpretation requires graphing water content vs. soil tension	Manual Readings
SEED's Soil Moisture Sensor	$100	Highly Accurate	5	Moderate	Easy to install, does not need calibration, can be interpreted by phone application.	Data Logger
Resistance Block	$300	High Accuracy	5	Low	Proper installation needed, electrical signal produced can be hooked up to data logger (no maintenance required)	Data Logger
Neutron Probe	$6,000	Highly Accurate	10	High	Large sampling volume: One probe for hundreds of site using PVC tubes. Requires soil-specific calibration. Safety hazard: requires trained and certified personnel.	Manual readings, Requires maintenance
Capacitance Probe	$13,000	Highly accurate	10	High	Small sampling volume. Installed once then checked over season. Careful installation required.	Data logger
Time Domain Reflectometry	$15,000	Highly Accurate	10	High	Bigger sample than capacitance but more power requirements. Installed once and then can be left in place.	(Depends) Can use data logger

With a focus on smallholder farmers in Africa, technologies like the neutron probe, capacitance probe and time domain reflectometry are automatically ruled out because they are extremely unaffordable and require either a high level of technical skill or considerable field maintenance.

In the context of a developing country, specifically Tanzania, several main design factors that should be taken into consideration are the level of accuracy needed, cost, technical skill level required, and amount of labor needed for operation. Therefore, we chose to compare SEED's technology with technologies that are relatively simple and inexpensive (i.e. the steel rod depth probe, tensiometer, and resistance block) to see where SEED's soil moisture sensor stands in comparison (Figure 2).

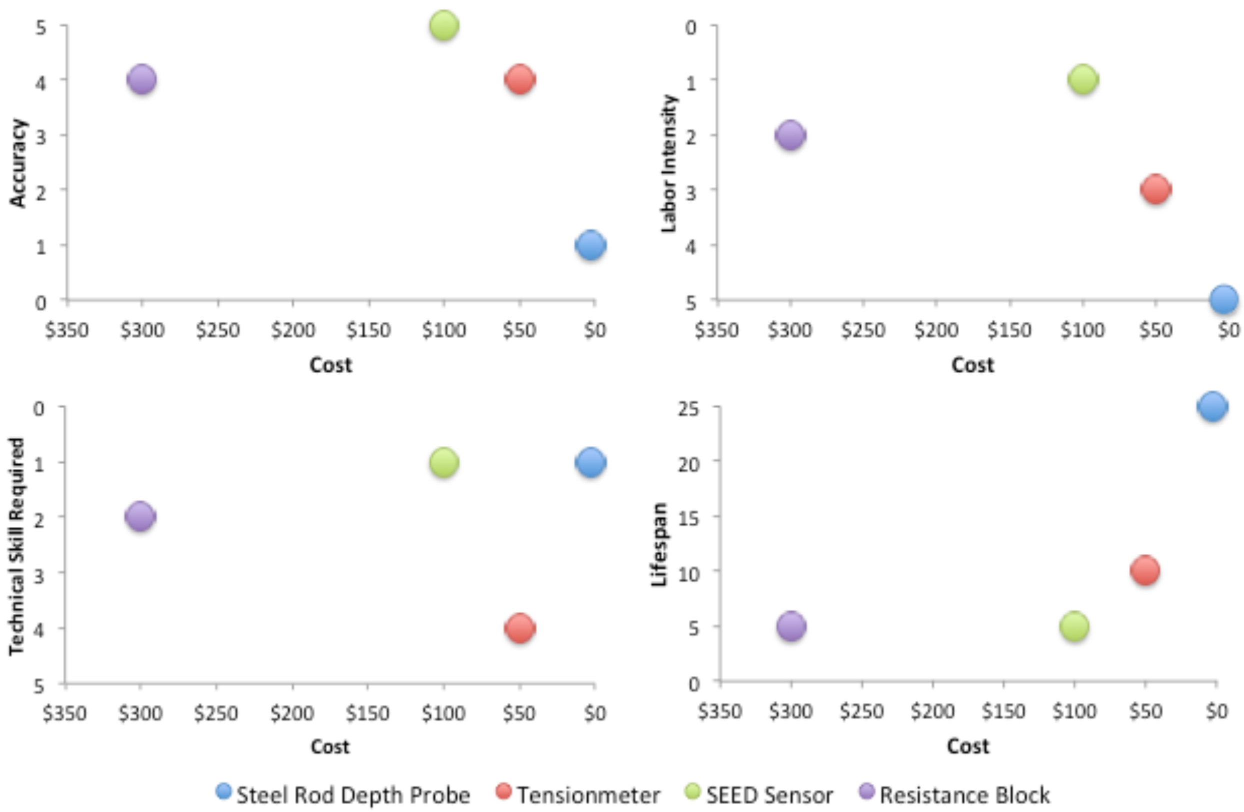

Figure 2. Comparison of the accuracy, labor intensity, technical skill required, and lifespan of existing soil moisture sensor technologies (< $300) with SEED soil moisture sensor prototype.

Starting with the steel rod depth probe, advantages of this technology are that it is the cheapest and requires the least level of technical skills. However, data collection requires a high amount of manual labor and it has the lowest level of accuracy: it only determines the depth of wetting and data output is very dependent on the farmer's knowledge.

The tensiometer produces higher level of accuracy, but tradeoffs associated are that it is relatively more expensive, requires a much higher level of technical skills and still requires a significant amount of time and labor from the farmer to take manual readings in the field.

The resistance block has high accuracy and is less labor intensive due to data collection by a data logger. However, it is considerably more expensive compared to the tensiometer. In addition, it requires proper installation and one major drawback is that as the block dissolves and degrades over time losing its calibration properties (Munoz-Carpena, 2004).

Lastly, SEED's technology that measures electrical conductivity promises highly accurate data. It does not require a high amount of labor as data is collected and sent automatically to the cloud real-time. To avoid the problem of interpretation, a visual output of blue for "irrigate" and red for "do not irrigate" using LED signals is developed, and data is analyzed in real-time by a phone application. Total cost for the technology is \$50 to \$100, which includes the sensor, a data logger, and a SIM card. Comparatively, SEED's soil moisture sensor is cheaper than the resistance block and but still provides the advantages that sophisticated technologies like the capacitance probes and time-domain reflectometry brings. Thus, SEED sensor technology is highly competitive technology that meets or outperforms similar low-cost sensors.

4.3 Commercial Opportunity

The commercial opportunity for a soil moisture sensor can be divided into four primary channels or organizations: 1) Non-governmental organizations (NGOs), 2) Financing institutions, 3) Private Agribusiness, and 4) Community-based or farmer organizations.

4.3.1 Stakeholder Analysis

Using the four identified channels for soil sensor distribution, a stakeholder analysis of the interest and influence of each major channel is conducted. Detailed in Table 10, high soil moisture sensor interest is primarily from farmers, private agribusiness, and microfinance institutes, which seek to gain significant profit.

Table 10. Analysis of Primary and Secondary stakeholders.

Stakeholders		Interest	Influence	Importance
Primary	Commercial farmers	• To have enough water for growing crops • To increase yield and productivity	Low	Directly affected (source of income)
	Small-scale farmers			
Secondary	Seed Enterprise	• Positive impact on community • Improve technical know-how • Profit	High	Directly affected
	Tanzania Govt.	• Conserve water	High	Indirectly affected
	Private agribusiness (Distributors)	• Profit	Moderate	Directly affected
	Microfinance Institutes	• Profit	Moderate	Directly affected
	Other NGOs	• Positive impact on community	Moderate	Indirectly affected

Further illustrated in Figure 3, while primary stakeholders, specifically small-scale farmers, can benefit the most from soil moisture sensor use, subsistence farmers possess low influence on other farmers and should not be a targeted channel for soil moisture sensor sale. Instead, channels with the highest potential for marketing and distribution of sensors are NGOs, agricultural distributors, and microfinance institutes.

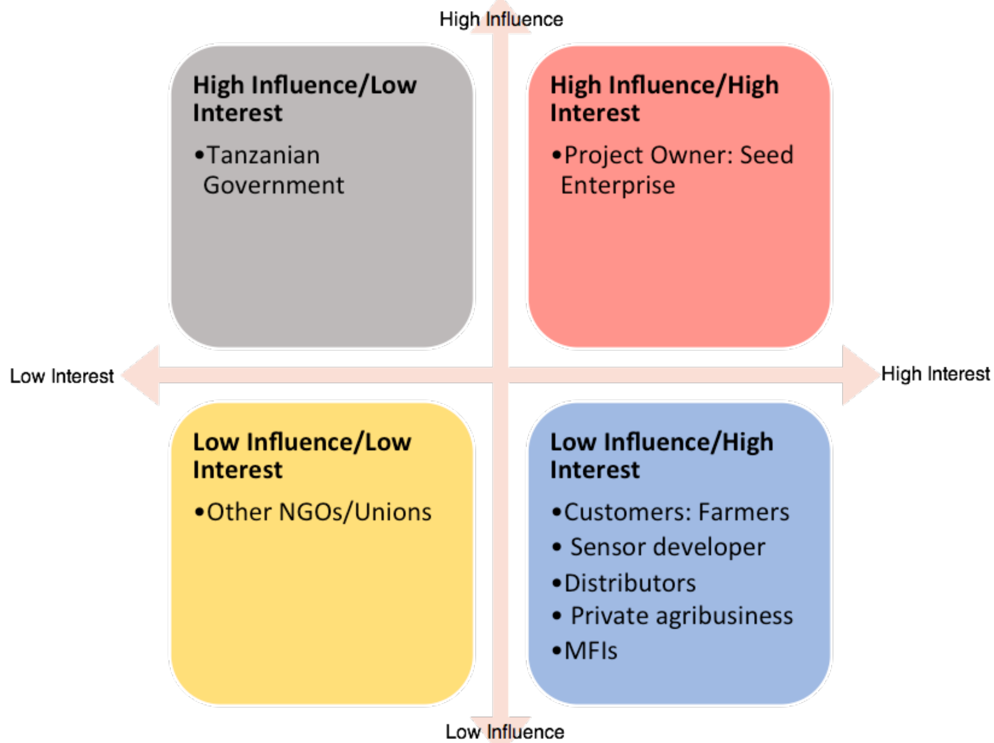

Figure 3. Influence-interest matrix for stakeholder analysis.

4.3.2 NGOs

One recommended channel is to market the soil moisture sensor is through NGOs such as One Acre Fund, Tanzania Agriculture Support Organization (TASO) which is based in Dar es Salaam, Fumbuka Agro Solution Organization (FASO), and VECO East Africa. These NGO's work closely with small-scale farmers in the different region in Tanzania to enhance agriculture productivity by implementing modern tools and technology, providing education and training in modern farming practices, and improving agricultural marketing.

Specifically these NGOs can help address lack of farmer understanding in the following areas: the entire product Life Cycle Costs, comparative product durability, and maintenance and disposal costs of a product. They disseminate publicity about the products through press conferences and advertisements. They cut down on expenses and help farmers to get the products at affordable prices.

4.3.3 Microfinance Institutions

The other channel is to market the soil moisture sensor through financial institutions. Two examples of major private institutions that work closely with consumers are: 1) Growth2Africa and 2) PRIDE Tanzania.

Growth2Africa is a private microfinance institution that is based in Dar es Salaam and is about seven years old. The company works as intermediary in raising funds for identified needs. The company targets individuals with productive businesses and uses a model that involves posting a loan on the MYC4 web for international individual investors to finance. It has a big potential if well explored. The idea is to come up with financing packages and technologies, market them to the users then link them with web sourced financing.

PRIDE Tanzania has operated in Tanzania since 1994. The company has a loan portfolio of over 27 million USD, and over 100,000 borrowers. The company uses a 'modified Grameen' method as its main methodology, which involves giving loans to members in groups. PRIDE has split its operations into PRIDE microfinance that does the traditional business lending and PRIDE NGO that does softer lending like sustainable technology loans development.

Partnership with microfinance institutions would provide farmers with a financing scheme to afford and pay off a soil moisture sensor in addition to increased marketing and advertising of the product.

4.4 Preliminary Market Research

Based on the conclusions drawn from the three primary focus areas (the need, desired design specifications, and commercial opportunity), preliminary market research was conducted to corroborate our findings and further narrow our scope. Specifically, organizations were contacted and asked to provide insight to following questions:

- What are the primary methods of irrigation?
- What crop would benefit most from soil moisture sensors (e.g. tobacco, rice, maize)?
- What design specifications/technology sophistication do you require in a sensor?
- How would you pay for a soil moisture sensor?

Of the original 18 organizations contacted for preliminary informal market research (Section 3.4, Table 4), five companies, all based in Tanzania, replied within the timeframe of this assessment. Detailed below in Table 11 are summaries of replies received from each organization. Because of contradicting information, low number of replies, and general consensus for a soil moisture sensor questionnaire, we concluded there is a need for a more formal and expansive market survey.

Table 11. Summary of replies received from several organizations regarding the potential market for soil moisture sensors.

Organization	Type	Interest in Product	Comments
FINCA	Microfinance	Mild	Currently occupied with other projects but interested in potentially collaborating for 2016
Ongeza Tanzania Ltd	Product Distribution	Low	Tanzania is not a good place for pilor trial: small-scale farmers are unwilling to invest in $100 drip irrigation so unlikely to buy soil moisture sensor
IRTECO	NGO	High	Requested questionnaire
ECHO East Africa Impact	NGO	High	Provided names of farming cooperatives and distribution companies to contact
YOSEFO	Microfinance	High	Requested questionnaire

4.4.1 Market Survey Formation

By request from several different organizations, a soil moisture sensor questionnaire was developed in collaboration with our client. Table 12 summarizes the key main questions addressed to stakeholders in the questionnaire. An initial draft of this questionnaire is found in Appendix A, and electronic copies were also sent to the original organizations that requested a survey. Using responses gathered, the soil moisture sensor questionnaire will be further refined and can be implemented in a Market Survey as part of the next phase of assessment, which is discussed in Section 5.1: Future Work.

Table 12. Main questions asked to stakeholders in preliminary soil moisture sensor questionnaire.

Sector	Qusetions
The Need	Do you need a soil moisture sensor? Have you seen a soil moisture sensor being used? When would you use a soil moisture sensor?
Desired Design Specifications	Do you want wireless/mobile capabilities? Do you want to sell it as a product or provide it as a service? How deep does the sensor need to be in the ground? What type of sensor do you prefer? How many sensors would you buy per hectare?
Commercial Opportunity	How much would you be willing to pay for soil moisture sensor? What type of financial program would you provide to your customers/users to sell this product?

5. Recommendations and Future Work

From literature review and economic scenario analysis, tobacco, highland rice, maize, and cotton are the Tanzanian agricultural products with the highest potential benefit from soil moisture sensor technology adoption. Amongst these crops, tobacco and rice offer the least-risk for small-scale farmer adoption due to a payback period of less than two years - even with minimal increases in crop productivity. In addition, tobacco and rice have significant proportion of irrigated farmlands, correlating to an already establish market for soil moisture sensors. Due to our client's ethical concerns regarding the tobacco industry, we conclude that rice is the most promising market for soil moisture sensors.

While there is a good market potential for soil moisture sensor products two keys aspects for effective market entry of soil moisture sensor should be addressed; (1) limited knowledge on the use and benefits of soil moisture sensor products, and (2) limited financing options for soil moisture sensor and agricultural technology products.

Limited knowledge of soil moisture sensor products arose due lack of information on available farm technology in the market and poor awareness among farmers on available farm technology that can be used to increase productivity and efficiency. In addition, several studies show that some farmers are not aware of manufacturers, importers, dealers and sellers who are involved in the agricultural technology business in Tanzania. It was emphasized that their contacts and locations cannot easily be found or established with certainty. Thus, working closely with NGOs and microfinance institutions can help bridge this knowledge gap and allow for technology adoption.

5.1 Future Work

Since soil moisture sensor technology in developing countries is relatively new, there are at least four appropriate ways to study the adoption of soil moisture sensor in Tanzania, 1) Market or intention surveys. 2) Historical analogy. 3) Cost models. 4) Diffusion models. Future market studies using one or many of these methods can address the social barriers and challenges identified in this assessment.

Market or intention surveys

The purpose of market surveys is to obtain information from decision makers on their decision-making criteria, technological preferences, and planned behavior. In addition, market surveys can be used to elicit responses from decision makers on their willingness to consider new technologies and on those factors the decision makers view as decisive. Market or intention surveys for new technologies can be accurate if certain conditions are met. However, one should be aware that there are several potential problem areas for market or intentions surveys. First, intentions and actual behavior are not identical. Expected future behaviors are subject to change and can change as a result of market forces not anticipated by the surveyor included in the survey's design. Second, the individuals answering the survey may not be in a sufficient authority position to actuate the planned behavior. Third, the individual may not be sufficiently knowledgeable of the new technology to assess the marketability of the new technology or its potential impact on the market. Fourth, the predictive power of the survey's planned behavioral responses is valid for a limited period of time (Packey, 1993).

This option is highly appealing as initial preliminary market research has already been conducted, and an initial soil moisture sensor questionnaire is in development. A formal market study of rice farmers in Tanzania, distribution companies, and farming cooperatives can be developed using our preliminary results and feedback.

Historical analogy

Historical analogy is a prediction method that compares an existing product's market pattern to a new product or technology. For this methodology, the market penetration path is assumed to be the same for both technologies. Historical analogy models generally assume that the technologies are of a sufficiently analogous nature as to exist in approximately identical market structures. If this is the case, then the new technology's market penetration share will approximate the existing technology's market penetration share's pattern over the technology's life cycle. The historical analogy model can be particularly useful for introducing new technology in different regions. However, the historical analogy model does not take into consideration non-time exogenous variables (Packey, 1993).

Cost Models

Cost models estimate market penetration as a function of the cost-related aspects of the product or technology. Cost estimates and the discount rate are typically used as the critical factors. For this approach, a range of technologies is selected, and the cost estimates are calculated. These cost estimates are then normalized and the comparative normalized cost of the technology is then used to calculate the product or technology's annual and long-run market share. Thus, cost models, on their own merit, are used to determine the adoption of new technologies. However, cost models are often combined with other model forms, such as diffusion models, to model market penetration (Packey, 1993).

Diffusion models

Diffusion models estimate the degree of entry of a new product into the marketplace. In general, diffusion models are composed of two segments: innovators and imitators. Innovators are individuals who are the first to spontaneously adopt new technologies. Here, spontaneous means that the innovators are not influenced by previous adopters but rather by some other external change agent, such as advertising. The imitator segment is influenced by' the number of people who have already purchased the product or technology. This segment will increase relative to the number of innovators over time as imitators are often influenced internally. Thus, innovators are influenced by mass-media communications (external) and imitators are influenced by word of-mouth communications (internal) with those who already have purchased (Packey, 1993).

6. Process Reflection

Cohesiveness was something that our group never failed to have despite different schedules, which made it hard to schedule meetings. The main reason our group had good cohesiveness and no conflict is because we were all focused on the same goal and our personalities gelled well together. As our group spent more time together, we began to develop our roles naturally.

We were very lucky to have the opportunity to talk with our client on a weekly basis, allowing both parties to remain informed and updated with our weekly progress. During these Skype sessions we reported the completed tasks from the previous week to the client, received feedback, and decided the planned tasks for the following week including who is responsible. We divided duties and roles equally with the exception of speeches, in which Sarah took charge.

In regards to decision-making and problem solving, our assessment was very iterative. As the soil moisture sensor is still in development phase, it was difficult to define our scope and understand the needs of the client (e.g. geographic area and target population). Despite our changing scope and methodology, our group excelled in collaborative thinking, and we were able to solve problems and make decisions very quickly. We attacked our challenges form multiple angles and approaches, and based on results discussed our future ideas and agreed on work to be completed for the following week.

We don't think we had any one leader as all provided leadership in different ways. Because we all possessed different backgrounds and styles of thinking, it kept us interested, and we found our experience new and unique. Not only did we learn more about how it is to work in groups, but we also learned something about ourselves.

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8. Appendices

Appendix A: Soil Moisture Sensor Questionnaire

Soil Moisture Sensor Questionnaire

Thank you very much for your time and consideration in filling out this questionnaire. Please read the following product description below and when finished answer the following questions. Your answers will greatly help our product development.

Product Description: SEED LLC, a social enterprise, has developed a low-cost soil moisture sensor to optimize irrigation and increase farm productivity. It uses proprietary technology to accurately collect and share soil-moisture data. The unique features of soil moisture device are that it does not require calibration based on soil type, it is easy to interpret, it visually displays when "to" and when "not to" irrigate using LED signals, and it has the capability to send data to the cloud real time as well as analyze in real-time.

Organization Name: ________________________

What is your role in the organization?

Need for soil moisture sensors:

1. Do you need a soil-moisture sensor?

   □ YES □ NO

   If yes, please describe why and how would you use it? And who are the direct customers and stakeholders of this technology?

Design features: How would you use a soil-moisture sensor?

1. Do you want wireless/mobile capability? □ Wireless □ Mobile capability
2. Do you want to sell it as a product or provide it as a service? □ Product □ Service □ Both
3. How deep does the sensor need to be in the ground?
4. Which type of sensor do you prefer: Steel rod, Tensiometer, or Resistance Block? Why?
   □ Steel Rod □ Tensiometer □ Resistance Block
5. How many would you need per hectare?

Commercial Opportunity:

1. How much would you be willing to pay for this soil moisture sensor?
   □ Up to $100 (one sensor package)
   □ Up to $200 (two sensor package)
   □ Up to $300 (four sensors package)

□ $200+ (multiple sensors, discounts based on package)
□ Others (pls explain more)

2. What type of financial program would you provide to your customers/users to sell this product?
□ Direct Cash payment
□ Credit (30/60/90 days)
□ Loan (1/2/5 year loans)
□ Microfinance
□ Others (pls explain more)

Additional Comments: