FERTIFY

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Improving Fertilizer Access and Usage in Low Yield Regions in Kenya

Final Report

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1 Project Requirements

1.1 Problem Statement

Farmers in low crop production regions in Kenya lack access to and knowledge of fertilizers, which has a negative impact on the amount of crops produced by these farmers. Fertilizer use increases production yields, allowing smallholder farmers to increase their revenue received from farming. This decrease in crop production leads to a feedback loop, in which farmers in low crop production regions are unable to afford fertilizer, resulting in lower yields, which in turn results in less revenue to purchase fertilizers. Thus, the purpose of this project is to increase fertilizer use and access to fertilizers in low crop production regions in Kenya, to enable farmers to produce more crops. The main clients of this design are farmers in low production yield areas in Kenya, who seek to increase their agricultural production.

1.2 Background Information and Context

1.2.1 General Background

Today's smallholder farmers in Kenya are far from a homogenous group. Their situation must be understood in terms of geographical, social and economic context. This is shown by the fact that the crop yields of smallholder farmers correlate greatly with a number of determinants. Farmers in regions where climate and soil conditions are favourable produce more crops, and factors such as gender, access to distributors, land ownership and fertilizer use are also decisive [1, 2, 3].

Among these factors, improved fertilizer use stands out as a challenge with particularly large potential impact. Although studies show that the use of mineral fertilizers typically increase yields by as much as 40-100% [4] and most stakeholders have incentives to increase fertilizer use, the usage remains low in Kenyans less fertile regions [1]. The interventions that have been attempted (such as government subsidies and "nudging" approaches) have had partial success [1, 5], but have benefitted the fertile regions of Western Kenya more than the more arid lands in the eastern parts of the country. This disparity in fertilizer usage may act as a feedback loop that perpetuates regional income inequalities.

1.2.2 Identification of Stakeholders

1.2.2.1 Smallholder Farmers

The primary stakeholders are the farmers themselves. They are responsible for the farming cycle from sowing to harvest and have strong economic incentives to increase the yields of their farmlands, while minimizing costs. These smallholder farmers are expected to be in a difficult financial situation and to face both institutional and psychological barriers to using fertilizers. Institutional barriers include low access to affordable credit, while important psychological barriers include the high risk of investing in fertilizer (upfront costs are relatively high and benefits are neither certain nor obvious) as well as time inconsistency (costs occur long before the benefits of the investment are reaped).

1.2.2.2 Fertilizer Distributors and Retailers

The fertilizer supply chain, however, does not start with the farmer. Two key challenges in increasing farmer access to fertilizers is to make sure that they are sold 1) in the physical proximity of the farmers and 2) at an affordable price [1]. Both challenges are questions of distribution. Distributors and retailers of fertilizers need customers and adequate profit margins to operate. They would subsequently likely be supportive of a solution that increases fertilizer demand and opposed to solutions that decreases demand (such as a tool for precision application). Furthermore, they would rather see high fertilizer prices than low, but may accept price drops if combined with lower distribution costs.

1.2.2.3 Microfinance Institutions

Fertilizers are a considerable investment for smallholder farmers in low-productivity regions. This is especially true since the availability of fertilizers is often at its highest at the time of sowing, long after the farmers have made a revenue from their harvest [5]. As such, they are often financed through credit. A solution that improves fertilizer access and usage has to be acceptable to the institutions that supply this credit. For example, a solution that depends on credit from microfinance institutions (MFIs) should reliably allow the farmer to repay this loan.

1.2.2.4 Local Authorities and National Government

Increased agricultural efficiency from improved fertilizer use is not only a concern of individual farmers. This is clearly shown by the engagement of the Kenyan government in the area, as discussed in 1.2.3.2. When smallholder farmers increase their profitability, they are in less need of government support in terms of social services and subsidies. Higher yields also increase the regional and national tax base and improve food security. In short, government authorities at both a local and national level have incentives to improve fertilizer access and usage.

1.2.3 Operating Environment

1.2.3.1 Physical Environment

Kenya contains several different agroclimatic zones (Figure 1) which can be divided into two categories: low-potential and high-potential regions. Generally, the low-production regions are those which have arid and very arid climates, and therefore have difficulty in reaching a high level of agricultural productivity and output. The high-production regions experience more humid climate, and therefore experience better baseline agricultural output.

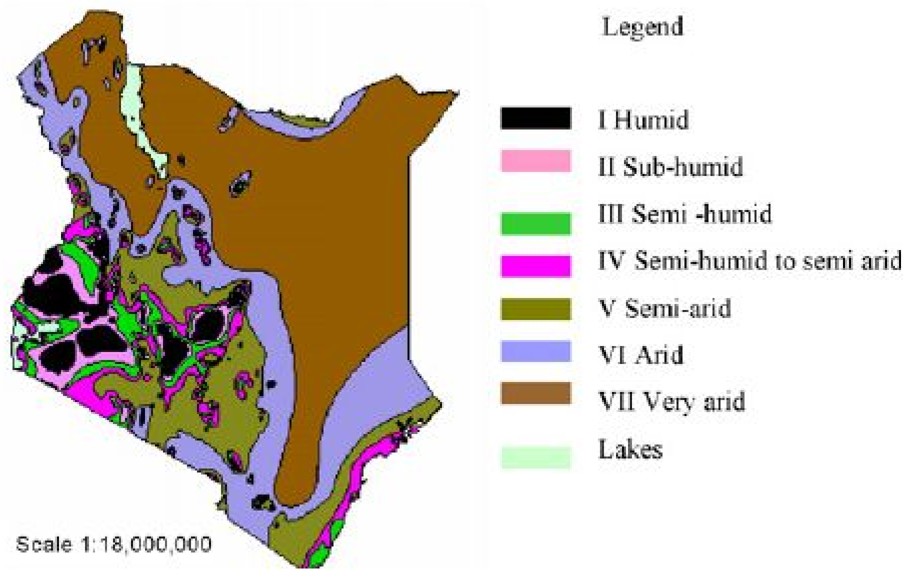

Figure 1: Agroclimatic zones in Kenya [6]

Fertilizer usage varies greatly between these two categories of regions; Table 1 contains each region and its corresponding fertilizer usage by percentage of households. Fertilizer usage is notably high in the high-productivity region, at 91% usage in households by 2007. The low-productivity region sees 26% usage of fertilizer in households, though this average must be qualified by realizing that two of the three zones in this region have only 11% and 13% usage. Evidently, the low-productivity region of Kenya has significant opportunity to improve agricultural outputs through increased fertilizer uptake. Figure 2 shows further evidence of this opportunity; it is apparent that organic carbon stocks are at their lowest in the low-productivity region of Kenya. Sufficient carbon stock improves soil fertility and structure, and thus improves agricultural yields [7].

Table 1: Share (%) of Kenyan maize-growing households that use fertilizer by zone [1]

Zone	1997	2000	2004	2007
High Potential Region				
Western transitional	41	65	71	81
High-potential maize zone	84	89	89	92
Western Highlands	78	90	91	95
Central Highlands	90	91	91	93
Subtotal	*77*	*85*	*86*	*91*
Low Potential Region				
Coastal Lowlands	4	4	5	11
Eastern Lowlands	26	27	47	48
Western lowlands	2	5	7	13
Subtotal	*12*	*14*	*23*	*26*
Total	**59**	**65**	**68**	**72**

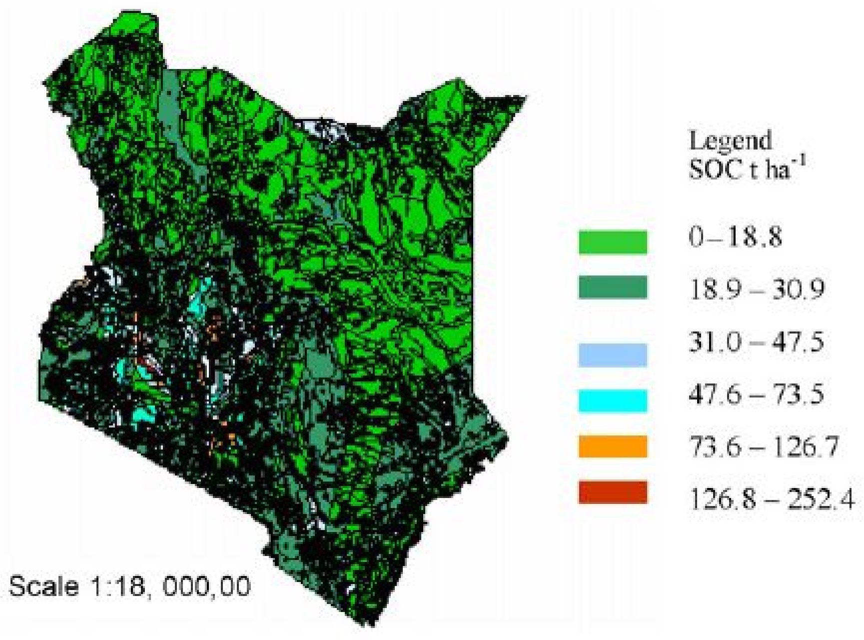

Figure 2: Soil organic carbon stocks in Kenya [6]

Smallholder farms are generally located in remote areas. Due to inadequate transportation infrastructure, this can pose a challenge to farmers. Poor roads are a barrier to accessing markets and services, and can lead to high transportation costs which drive up the price of commodities [3].

1.2.3.2 Political Environment

Historically, fertilizer usage has been closely tied to the Kenyan government's political activity and policy-making. In the 1980s, the government held very tight control over the agricultural industry, including fertilizer availability and pricing. Though intended to increase affordability, this controlled pricing eliminated the possibility for retailers to profit from the sale of fertilizer due to the high cost of transporting the product to remote, rural locations [1]. To undo the market inefficiencies and the high regulatory burden inflicted by this system, the government reduced their control over the market in the 1990s to allow private companies to trade and distribute fertilizer freely in Kenya. This led to increased distribution and penetration into remote areas of the country [1].

In 2007, global fertilizer prices rose sharply. This event led to resumed government involvement in the market, this time through the form of large subsidies [1]. However, the continued provision of these subsidies may be unsustainable for the government due to lack of financial resources, and international partners may be required to assume some of the financial responsibility [1].

1.2.3.3 Cultural and Social Environment

Kenya has a population of 48.46 million as of 2016; of this total, 73.95% is comprised of rural dwellers [8]. There are around 40 distinct ethnic groups who each speak a variety of languages. The official languages of Kenya are English and Kiswahili.

Though fees for primary and secondary education in Kenya were abolished, there still exist indirect costs and barriers to access which lead to low enrolment of poor and female students [9]. 38.5% of the adult Kenyan population is illiterate, though there exist large disparities in illiteracy by geographic area [10]; rural areas tend to have lower literacy rates than urban areas.

Society and family structures in Kenya are patriarchal in nature. Men control much of the decision making and distribution of resources at the household level, which inhibits women's access to asset ownership and property rights [11]. These obstacles create barriers to women's full ability to participate in and benefit from the economic benefits of agriculture [12].

As of 2006, 49% of Kenya's rural population lives below the poverty line [13]. The status of poverty is not static; it can change year to year depending on unpredictable weather conditions and seasonality, due to the fact that agriculture comprises a large part of rural households' income.

1.2.3.4 Digital Environment

In 2016, there were 81 active mobile phone subscriptions per 100 Kenyans, according to the World Bank [14]. 26% of the population were internet users, and the number has been increasing by 5 percentage points per year in the last years [15]. Thanks to the mobile payment system M-PESA, that has been in wide use in Kenya since 2007, researchers from MIT estimate that 96% of all Kenyan household have at least one member with access to an

SMS-based money transfer service [16]. However, all these data points are national averages, and information concerning regional variability is sparse.

1.2.4 Market Issues and Economic Context

1.2.4.1 Smallholder Farmers

Smallholder farmers operate in the same style as entrepreneurs: they are responsible for raising capital to invest in productive assets [3]. These farm operations are subject to risks in the form of unpredictable weather and price surges at market. As the supply chain changes and supermarkets become primary customers, smallholder farmers face challenges due to pressure for their farms to expand and commercialize; they often face marginalization if they are unable to meet increasingly high standards [3, 12]. This marginalization has a socioeconomic connotation: farmers who sell to supermarkets tend to be "more educated, have more access to information, are able to hire-in labour, have greater access to irrigation and are closer to transport infrastructure [12]." Women and those who have obtained only a low level of education are therefore at a disadvantage, being less likely to grow or prosper due to their smaller scale and limited access to resources [12]. This acts to reinforce the cycle of poverty and aggravates the problem of income inequality.

The average smallholder farm in Kenya is 0.47 hectares [3]. 15.9 million Kenyans are smallholder farmers or belong to such a family unit [3]. Small farms produce 63% of the country's food [3]. Maize, a dominant component of the Kenyan diet, comprises half of the country's smallholder production [3], and smallholder farmers generally choose to grow several crops in order to diversify and insulate themselves from risk (Figure 3).

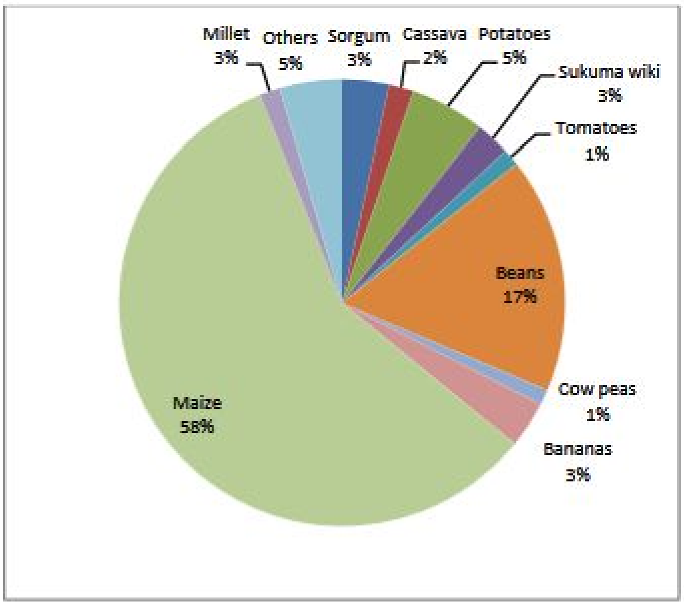

Figure 3: Kenya smallholder farmers' crop diversification [3]

Lack of access to capital is an obstacle to the growth of smallholder farmers. The average Kenyan smallholder farmer's annual income is $2,527 USD [3] (using 2009 conversion rates), and it is estimated that an annual product cost exceeding 5% of their income will require subsidy. Because of their small scale and high risk, they are often not perceived to be safe candidates for loans. This results in an inability to purchase useful assets such as tractors, irrigation equipment, and seeders, and also inhibits purchase of agricultural inputs such as fertilizer [3]. Though these assets and inputs have the opportunity to increase yields and provide large returns on their purchase price, the capital costs prohibit access for many.

The future of smallholder farms is uncertain; their productivity is increasing at a slower rate than other farm sizes [3], which endangers their economic viability and ability to participate in the market.

1.2.4.2 Fertilizer

Through field experiments in Kenya, fertilizer increased yields by 40 to 100% [4]. This much-needed increase in yield can provide more food for the smallholder farmer's consumption, provide a source of revenue to the farmer, or a combination of each. The result is improved food security and improved economic standing. Few smallholder farms in the low-potential zones of Kenya can afford mineral fertilizers; of those who do purchase them, the average application is 22 kg per acre [1]; this is significantly lower than in other parts of the world. Indeed, it falls short of the 123 kg per acre recommended for application by African leaders [2]. Thus, there are significant opportunities to improve the economic standing of smallholder farmers through increasing their access and usage of fertilizer.

In Kenya's low-potential region, female-headed households have a 6% lower market participation rate in the purchase of fertilizer than male-led households, and a 28% lower fertilizer application density than male-led households [1]. This shows there is not only a gap between market participation, but also in the quantity of product a household is able to afford.

Geographic location also affects a farmer's ability to participate in the market: for every additional 1 km in distance away from a fertilizer retailer the farm is located, the likelihood of the farmer participating in the market decreases by 1% [1]. This shows that penetration of retailers and distribution networks is crucial to ensure access to fertilizer and uptake by farmers.

In a broader economic context, several market factors have been identified which could contribute (and may have contributed in the past) to increasing the affordability of fertilizer. As described in the World Bank's report, "Fertilizer in Kenya: Factors Driving the Increase in Usage by Smallholder Farmers," [1] these factors are as follows:

1. Reducing the cost of backend transportation, and improving the availability of trucks;
2. Improving private importers' ability to access international credit, which provides the opportunity for lower credit rates than those available domestically;
3. The merging of international and local firms has been identified as a method to share local knowledge, and thus improve efficiency of operations in rural areas; and
4. Increasing competition between private wholesalers has resulted in an increase in distribution firms.

1.3 Functions

1.3.1 Primary Function

The design shall improve fertilizer usage for smallholder farmers in low production regions in Kenya.

1.3.2 Secondary Functions

The secondary functions of this design are to improve:

1. Access to fertilizer
2. Application of fertilizer

1.3.3 Tertiary Functions

The secondary functions can be further broken down into the following tertiary functions:

1. Improve availability of information about fertilizer and its correct application methods
2. Improve geographical availability (i.e. distribution costs) in order to ensure the fertilizer can get to the customer, or vice-versa
3. Improve financing opportunities

1.3.4 Unintended Functions

The following are unintended functions, which could develop as a consequence of the final design. The final design could:

- Affect the current fertilizer distribution chain adversely
- Affect soil quality (positively or negatively)
- Affect quality of waterways due to runoff

1.4 Objectives

The following are the objectives of the design, and have been ranked in order of importance based on the needs of the primary customer:

1. Maximize smallholder farmer profits from their yield
2. Minimize cost to smallholder farmers such that it is manageable (both in absolute cost and the time of year when cost is incurred)
3. Maximize accessibility to remote areas
4. Maximize accessibility of solution to those of all education levels
5. Maximize long term product sustainability
6. Minimize damage to livelihoods of retailers and distributors

1.5 Constraints

The following constraints must be adhered to and considered in the final design. The design:

- Must comply with all regional and national regulations

- Must not decrease soil quality in the long term (using nutrient density at time of implementation as a baseline value)
- Must not bring harm to the operator
- Must not adversely affect agricultural outputs.

2 Research into the State of the Art

2.1 Discussion of Search Domain

In this section, the team discusses the search domain used to determine the existence of any solutions or patents, along with other relevant companies, which aim to address the problem. The team researched existing startups in the fertilizer or small-scale agriculture industry in Kenya, Sub-Saharan Africa and the rest of the world to benchmark and determine if solutions exist. The team also completed research on interventions (such as government related interventions) to increase fertilizer use. Finally, the team attempted to find existing patents for designs which already address the problem, on Google Patents and the United States Patent and Trademark Office (USPTO).

2.2 Commercially Available Solutions

FarmDrive [17] is a Kenyan startup aimed at helping financial institutions determine the credit rating of smallholder farmers. This, in turn, enables the farmers to access low-cost capital to invest in agricultural inputs and equipment. In 2017, the service had 3000 registered users and a total of $130,000 in loans had been disbursed to 400 farmers. FarmDrive acts as an intermediary between the banks and the farmers, and it is not clear how they are funded or generate revenue. Their service is, however, an interesting way of solving the financing problem of fertilizer access [18].

Apollo Agriculture aims to maximize the profits of farmers in emerging markets by "delivering input finance and customized advice" [19]. Their approach is software- and data-intensive and seems to emphasize financing and information. However, very few details regarding their product offerings are available at this time.

Wefarm [20] is a decentralized, SMS-based information platform for smallholder farmers worldwide. Any registered user can send text messages with farming-related questions to a central Wefarm number, and the questions are then distributed to other farmers in the Wefarm community. The idea is that the asker will get a relevant response from others who are in a similar situation. Wefarm attempts to solve a wide range of information problems for smallholder farmers and appears to do so successfully, judging from its almost 700,000 registered users.

2.3 Patent Literature

The team completed research regarding patents on the USPTO and Google Patents involving the improvement of fertilizer access or use to customers, and identified three patents on solutions relevant to this problem. The first patent is for a system which takes information from the customer regarding land fertility, crop nutrition and composition of the soil, informing the customer what type of fertilizer the soil needs [21]. Another patent combines inorganic and organic fertilizer, including organic waste, in order to produce the fertilizer [22]. The third patent is for a "bioactive nutrient fortified fertilizer", and includes material from bioactivated nutrients [23].

2.4 Other Relevant Designs

From 2003 to 2005, researchers from the MIT Poverty Action Lab investigated what interventions were the most effective in increasing fertilizer use in Western Kenya [5]. Fertilizers were being offered at different points in time and at different subsidy levels, and the researchers studied how many smallholder farmers accepted the offers, and if so, whether they continued to use fertilizer in subsequent growing seasons.

The conclusion from the study was that offering fertilizer in person at the time of harvest (when farmers had money available) without subsidies improved fertilizer use as much as a 50% price subsidy offered 2-4 months later (adoption rate increases of 14 and 13 percentage points, respectively). This result strongly emphasizes the importance of payment and delivery conditions.

Interestingly, farmers that bought fertilizer at the time of harvest were *not* more likely to use fertilizer in subsequent growing seasons, when the program was not offered. This suggests that offering flexible payment and delivery terms at a single occasion is insufficient to ensure continued fertilizer use.

2.5 Conclusions

The team found several start-ups in Kenya which aim to provide Kenyans with the financial means to purchase fertilizer, and several which aim to provide Kenyans with the knowledge they require to apply the fertilizer. The team also found a patent on an existing idea which aims to provide Kenyan farmers with knowledge about the type of fertilizer they require, along with patents for innovative products which could act as fertilizer. Finally, the team found evidence showing that Kenyans are more likely to purchase and apply fertilizer which is cheaper and more accessible to them.

The existing solutions either focus on providing fertilizer to customers, or providing information about fertilizer use to customers. Hence, they do not completely solve the problem of fertilizer access and use in Kenya. In order to ensure that the limitations of some of the existing solutions are complemented by the strengths of other solutions, the team will take this information into consideration when developing potential solutions to this problem.

3 Detailed Design Specification

3.1 Explanation and Assessment of Final Design

Smallholder farmers' access to fertilizer is challenged in several ways:

i. The farm's geographic location,
ii. The fertilizer's high capital cost; this cost is incurred by farmers at a time during the year when they may not possess the necessary funds for purchase.
iii. The lack of information surrounding fertilizer application, including quantity, type, frequency and timing of application

By providing fertilizer as a service, the team aims to reduce the barriers customers face when purchasing fertilizer.

The first step in the service is soil testing. Soil testing services - provided by an affiliate such as SoilCares [24] - will be deployed to each customer's farm to assess the unique soil needs, such as nutrient density and acidity. The results of this test will determine the blend of fertilizer that the customer receives. This tailored, in-house blended product allows the team to meet the exact needs of each farmer, and reflects the regional variance of nutrient density in soil as well as crop selection.

Customers will pay a monthly fee rather than an upfront cost to purchase their fertilizer. They will receive two shipments of fertilizer per year - one for each growing cycle - in the months of March and October. By distributing payments throughout the year, the team aims to increase the affordability of the product. Payments will be facilitated through M-Pesa, a widely available payment product in Kenya.

Fertilizer will be delivered in the exact quantity required for the customer's field size. Included in the shipment will be a sized scoop to ensure the correct quantity of fertilizer is applied to each plant, and that the product will be evenly applied to the field.

Tailor-made fertilizer blends will be created by purchasing different varieties of fertilizer, and blending them to create custom products. For example, NPK fertilizer is sold in different nutrient ratios; by purchasing existing products that contain different ratios of nutrients, mixing can create the required ratio of nutrients for each customer.

By delivering product twice per year, transportation costs are minimized. However, fertilizer must be applied at specific times in each of the two growing cycles, and application timing and method are vital to maximizing the effectiveness of the product. To deliver this information, a text-based SMS system will be incorporated into the service to instruct users how and when to apply the fertilizer to the land. Additionally, the SMS system will provide information to the customers to help ensure the fertilizer is able to work to the best of its ability.

Farmers may be unable to pay the monthly payments during their first year as customers due to past low yields and a lack of money. To offset the first years' costs, partnerships with charitable organizations could be pursued to provide subsidies to customers. In subsequent years, it is assumed that the customers will be able to pay the monthly fee without financial assistance due to income from increased crop yields.

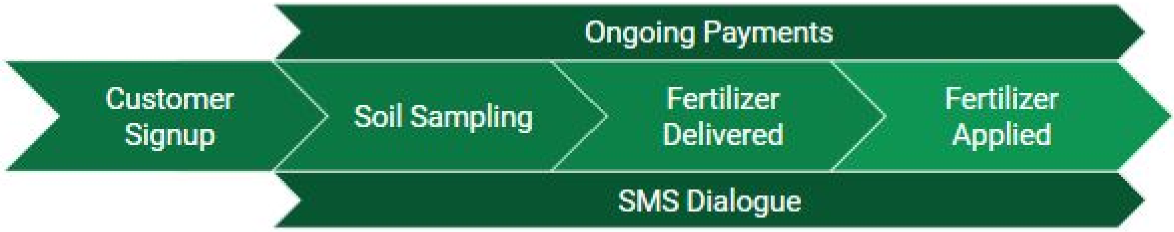

Figure 4: Process of the service's activities in the context of the customer

In order to assess the service's impact on crop yield, the first year of roll out would act as a pilot for the program, and approximately ten farms would be involved. The purpose of this is to maintain a controlled environment which will generate quantitative and qualitative results for analysis. Most importantly, improvement in crop yield could be assessed while identifying other factors which may have hindered yields; general impact upon the family could also be assessed. Furthermore, a pilot would allow the team to solicit feedback from users which would be incorporated into the service to increase the chances of success of the subsequent wide roll out. A longer-term goal is to perform a randomized control trial to add further insight into the service's impact upon farmers; these trials are resource intensive however, and thus not feasible to perform immediately. Furthermore, the team would require partners from NGOs or academia to perform this trial.

3.2 Compliance with Regulations and Standards

Regulation in Kenya on inorganic fertilizer states that "no person shall import, manufacture, compound, mix or sell any fertilizer...other than a substance declared by rule made under...this act to be an approved fertilizer" [25]. After digging further into the act to identify exactly what types of fertilizers are regulated, it was found that "no person shall import any fertilizer or animal foodstuff which contains bone or any other substance derived from an animal carcass" [25].

Additionally, it is also against the law in Kenya to sell any fertilizer containing substances derived from animal carcasses (unless they have been sterilized in the required manner) or fertilizers containing deleterious ingredients [25]. Finally, fertilizer must be stored properly and if an inspector asks to test or inspect the fertilizer, the team has to allow them to do so. Given that the final design is an inorganic fertilizer, which does not contain deleterious ingredients and will be stored properly in a building, the team does not believe that the final design infringes these constraints.

3.3 Intellectual Property (IP) Considerations

Given that the distribution of inorganic fertilizer does not infringe on the identified patents in section 2.3, the team believes that it is unlikely that the final design would infringe on existing IP. Moreover, since the final design involves the distribution of a product which already exists and is not a new idea, the design does not appear to be patentable.

4.4 Life Cycle and Environmental Impact

Inorganic fertilizers are traditionally produced using large quantities of fossil fuels. A life cycle assessment of large-scale production shows emissions of about 1 kilogram of CO_{2eq} per kilogram of fertilizer [26]. For a maize farmer with 0.5 hectares of land, the emission increase associated with using a 50 kg bag of fertilizer would be in the range of 0.05-0.1 tonnes of CO_{2eq} per year, which is a small but not insignificant increase. As a comparison relevant to Northern Kenya, where the largest part of the population lives off livestock, the increase is less than 5% of the yearly CO_{2eq} emissions from a single cow [27, 28]. If increased fertilizer access can make it easier for pastoralists who wish to transition to crop farming, then the net climate effect will be significantly positive. The same applies for farmers that have previously used fertilizers in large quantities and switch to this service.

Two key ingredients of inorganic fertilizers are nitrogen and phosphorus. Discharge of these substances into natural systems is the most significant driver of aquatic eutrophication [29]. This has historically been a problem in certain parts of Kenya, notably in Lake Victoria [30] and Lake Naivasha [31]. However, both of these lakes are located in southwestern Kenya, where fertilizer use is much higher than in the eastern regions (see section 1.2), and there is little information to suggest that eutrophication is a serious problem in the regions targeted by this service.

3.5 Economics and Market Issues

Farmers' purchase of fertilizer is heavily subsidised by the Kenyan government. Without subsidy, NPK fertilizer costs 3,200 Ksh; with the subsidy, it costs 1,800 Ksh [32]. This is a 44% reduction in price. In the absence of research, it is difficult to estimate the change in affordability and purchasing based on a unit decrease in fertilizer cost; however, it is likely safe to predict that price decrease will improve uptake of fertilizer. Further research is required to determine if this subsidy has increased the product affordability for the poorest smallholder farmers.

Fertify is likely to be economically viable. Though there are additional costs on top of the bag of fertilizer which fall onto the customer (see section 4.3.2 for a full overview of costs), the additional value added by soil testing and personalized product in conjunction with the monthly payment system will allow the service to be financially accessible.

4 Implementation Requirements and Plan

4.1 Creating Value

4.1.1 Customers

This service is aimed at smallholder maize farmers in low-yield regions of Kenya, which includes the eastern coastal area and the northern regions bordering Somalia and Ethiopia. The strongest reason to target these areas is that fertilizer usage rates among maize farmers there are much lower than in the more fertile western regions. In 2009, about 12 million people lived in these areas [33]. Smallholder farmers in Kenya cultivate an average of 0.47 hectares of land, half of which is used to produce maize [3].

4.1.2 Value Proposition

The application of fertilizer could increase crop yields for smallholder farmers by as much as 40% to 100% [4]. This increase in crop yields leads to more food for smallholder farmers, in addition to a higher income from selling the crops.

The subscription payment model has two significant advantages. Firstly, it spreads out the large investment of fertilizer over several smaller payments. This eliminates the need for farmers to put away money for months in order to buy fertilizer. Secondly, it transforms the choice of using fertilizer from an opt-in (the farmer needs to actively choose to visit a retailer and buy fertilizer) to an opt-out (where the farmer will have paid for fertilizer by the time of the sowing season, unless he or she actively chooses to cancel the subscription). This is a powerful change in mindset.

The proposed service also includes several mechanisms to facilitate the practical application of fertilizer. The customers receive the optimal blend and quantity of fertilizer for their land, minimizing the risk that they pay for too much or for the wrong kind of fertilizer. The subscription model includes continuous information such as timely reminders of when fertilizer should be applied and current crop prices in cities at the time of harvest. All in all, the model is designed to nudge profitable fertilizer use and empower farmers to make better decisions regarding their land.

4.1.3 Channel

A successful fertilizer distribution system must carefully balance the trade-offs between customer accessibility and delivery costs. Low customer accessibility (such as limiting distribution to major towns) will greatly hinder customer adoption of the service, while high costs (such as personalized deliveries) could make the service unaffordable to the target group. The proposed solution to this problem is to serve groups of smallholder farmers located in the proximity of a number of villages. Pending further research and data collection into the density of farms in Kenya, farmers would either receive their fertilizer shipment directly to their farm or deliveries would be made to a central location in a nearby village to be retrieved by farmers in the surrounding area.

Assuming 10 customers per village, this would reduce the number of deliveries by an order of magnitude compared to direct deliveries. Deliveries could be performed either by renting a vehicle or by partnering with an existing shipping and distribution company. Due to limited availability of information about the costs of each of these options, further research is required to determine which is more cost-effective. For the purpose of cost estimates, shipping costs are modelled off of a quote from an existing shipping company in Kenya.

This system assumes that the density of farmers is high enough for several farmers to be able to reach a certain geographical point conveniently. This is likely to be the case in most places; most Kenyan children go to a school, and it's reasonable to believe that even smallholder farmers sometimes need to visit a general retailer or community centre. In the early stages of deployment, however, marketing efforts may need to exclude the most remotely located farmers.

4.1.4 Customer Relationships

Finding and retaining customers for a year-round fertilizer subscription requires successful management of customer relationships. A successful customer relationship management (CRM) strategy must answer two questions:

i. How can potential customers be found and encouraged to adopt the service?
ii. What communication between the service provider and the farmers is optimal in ensuring customer retention and satisfaction?

For the first one or two growing seasons, the program would be run as a pilot with about 10 customers in an appropriate geographical area. During this period, customer interaction is especially important for the service provider to understand how the service is being used in practice. Data could be collected through home visits, focus groups and SMS surveys. Personal interactions do not only help to improve the service, but also foster customer loyalty. A successful pilot will also make it easier to subsequently persuade new users to try the service, and create a snowball effect of adoption.

In the longer run, a promising way to reach potential customers would be to come into contact with key players in the current distribution chain that would benefit if the smallholder farmers in question used more fertilizers. One such player could be whoever currently buys the crops from these farmers and brings them to market. By partnering with local crop wholesalers, the team could come into contact with most smallholder maize farmers in the relevant areas. This would be in the interest of the wholesalers, since they would have access to larger quantities of crops in the same geographical area as yields increase because of fertilizer usage. At a future stage, partnerships with wholesalers could be developed further, for example by having them deliver fertilizers as they pick up every farmer's crops. Another promising way of reaching new customers would be a referral system where current customers receive discounts in the form of account credits if they encourage acquaintances to sign up for the service.

The second question is that of maintaining efficient communication with customers. Research indicates that access to mobile phones and mobile payment systems is widespread across Kenya. Text messaging is an extremely affordable and efficient way of maintaining two-way communication with customers, as successfully shown by other organizations such as WeFarm. Some services that could be provided through text messaging include:

- fertilizer delivery information such as dates and quantities
- payment reminders
- fertilizer application reminders and instructions
- subscription renewal information
- crop price information from local cities

Cumulatively, the goal of this communication channel is to deliver sufficient value to the customers to ensure that they remain customers. This is especially important during the months when they are not delivered fertilizers, and the benefits of the subscription are less tangible. As smallholder farmers start transitioning to smart phones, the team could explore options to develop an app for communicating with customers as future work.

4.2 Deliver Value

4.2.1 Key Activities

- **Purchasing fertilizer.** This will be a key activity since the main operating costs of the service are purchasing costs and distribution costs. The affordability of the service will subsequently correlate strongly with the price that the team would pay for the fertilizer. If the team could procure fertilizer in bulk with good delivery conditions, lower prices could potentially be offered to end customers.
- **Soil sampling.** The goal of the service is to deliver a customized fertilizer that caters to the need of every farmer. To do so, each customer's soil characteristics must be measured or estimated. In many cases, it would hopefully be adequate to test the soil in a number of clusters and interpolate the results to the customers in the region. These tests would be conducted annually for each cluster, and the customers in the area would receive a blend of fertilizer that specifically addresses the nutrient deficiencies in that area.
- **Mixing and repackaging the fertilizer.** This activity adds value by ensuring that each customer receives the correct amount of blended fertilizer that caters to the needs of the individual farm. The mixing and repackaging would take place once per growing season (i.e., bi-annually) in a warehouse. Different NPK blends will be mixed into a new bag for each customer in proportions depending on soil quality of that customer's land and in the quantity required by each customer.
- **Delivering the fertilizer.** Before every growing season, each customer's bag of fertilizer will be delivered to their farm. By initially focusing marketing efforts at certain villages, the team will ensure that these deliveries are feasible. In areas where customer density is sparse, a possible alternative is to deliver several customers' bags to a single delivery point such as a local villages instead of delivering to their doorstep.

- **Delivering information on usage via text.** This activity is thoroughly described in the customer relationships section.
- **Marketing to customers.** After the trial stage and proof of concept, a key activity of the program will be to find suitable customers to whom the service can be marketed. Possible marketing strategies are explained in the Customer Relationships section.
- **Creating partnerships.** The program is heavily dependent on rewarding partnerships for funding, procurement, and distribution. Creating and maintaining these partnerships will require significant resources, particularly in the early stages of the program.

4.2.2 Key Resources

- **Financial resources.** Since the cost structure of the service is dominated by seasonal costs (such as warehouse rent) and variable costs (such as fertilizer purchase), the initial funding required for one-time costs is low. However, the business model is partly dependant on economies of scale for cheaper fertilizer procurement and distribution. During the first years, when the number of customers would be small, the business would likely operate at a loss. This loss would need to be covered by investments or grants:
  - The grants the team can apply for from organizations such as KALRO
  - Possible loans could come from the government
- **Physical resources.** Most resources required to run the enterprise would be needed only on a seasonal basis in the weeks preceding each growing season. These resources include the rented warehouse facility and a rented truck (if the arrangement of third-party deliveries is infeasible).
- **Human resources.** Knowledge of local conditions is a crucial success factor for the service. This knowledge can be divided into three main categories:
  - *Local soil and agricultural expertise.* This knowledge is useful in determining optimal fertilizer composition and quantities as well as in delivering relevant and correct information to the customers. Academic researchers and NGOs (such as KALRO) are both promising partners in attaining this expertise.
  - *Distribution network knowledge*. The service must be designed in a way that is compatible with the current value chain of smallholder farmers. Knowing how these networks function will be valuable for marketing and operational reasons.
  - *Generic local problem-solving savvy*. Starting an enterprise requires a great deal of ad-hoc logistical problem-solving. This skill is highly local and would need to be a part of the organisation.
- **Intellectual resources**. With ambitious measurement and growing numbers of customers, the program would rather quickly collect data on crop yields, fertilizer usage, incomes, etc. This data could be used internally to more efficiently target the farmers that are likely to benefit the most from the service, and shared externally for research purposes. Although the fertilizer market is traditionally undiversified, developing a recognisable brand could also contribute to the success of the program.

4.2.3 Key Partners

- **Soil testing partners.** SoilCares is an organization which will be required to perform soil testing for customers, which will be used to ensure customers are receiving the required mixture of fertilizer. Other soil testing companies could also be explored as alternatives.
- **Government.** A partnership could be formed with the government to subsidize the service in order to make it more affordable for customers.
- **Transportation and distribution**. Partnerships can be pursued with existing distribution companies to ease in the delivery of the fertilizer product.
- **Fertilizer companies.** The team will purchase fertilizer from existing fertilizer retailers or wholesalers.
- **KALRO.** Nonprofit focussing on research and development in agriculture, with whom the team could partner to guide the implementation of the plan [34]
- **World Vision.** World Vision can provide expertise and connections with local knowledge in addition to funding for the implementation of the program.

4.3 Financials

4.3.1 Revenue

Revenue comes from selling the product, and is determined by the product's price. Please refer to the Profit/Breakeven section for an outline of the required pricing in order to break even, and also to turn a 5% profit.

Pricing will be set based upon what is affordable for the customer. In the first few years of the service's existence, customer base may be low and thus the cost to the customer would theoretically be high. To mitigate this, the team plans to partner with organizations able to provide funds to subsidize the cost of the service, if necessary. As the customer base grows, the cost to the customer will fall thanks to a wider base of customers across which the fixed costs are distributed.

4.3.2 Costs

The following table provides an overview of the costs associated with the service. Detailed descriptions are found below.

Table 3: Summary of business costs given 100 customers

Fixed/Variable	**Cost Name**	**Unit**	**Yearly Quantity**	**Cost per Unit (Ksh)**	**Total Cost/year (Ksh)**	**Perc. of Costs**
Fixed	Warehouse rent	month	2	70000	140000	24%
Fixed	Business License	-	1	10500	10500	2%
Variable	fertilizer purchase	bags of 50 kg	200	1800	360000	61%

Variable	Distribution Cost	km	600	95	57000	10%
Variable	Labour	hours	130	64.55	8391.5	1%
Variable	Soil Testing	number of tests	10	1300	13000	2%

Fixed costs - those which do not increase with number of customers - are listed below:

- **Warehouse rental.** For two weeks, twice per year, a small warehouse will be required to store the purchased fertilizer. Additionally, this will provide the space required to perform the mixing of fertilizer to create the final tailor-made products. Warehouse rentals are generally available in monthly increments, and so two months of space rental costs approximately 140,000 Ksh per year [35].
- **Business license.** This is a one-time cost of 10,500 KSh [36].

Variable costs - that is, all costs that scale based on the number of customers - are listed here:

- **Fertilizer purchases.** Annually, and on average, each farm will require 50 kg of fertilizer for each of the two growing seasons. At a cost of 1,800 KSh per bag, this will cost 3,600 Ksh per customer [32]. Fertilizer is available at this price when subsidized by the Kenyan government. As operations and customer base grows, fertilizer could instead be purchased in bulk directly from an importer if this was found to decrease the cost per kilogram of product.
- **Transportation costs.** There are two stages of transportation: transporting the fertilizer from its point of purchase to the warehouse, and later delivering the product to the customers. A truck will be rented to perform these actions. It is estimated that the pickup and delivery will require 300 km of distance driven per year, plus an additional 3 km per additional customer. This will cost approximately 95 KSh per km [37].
- **Labour.** It is estimated that processing the fertilizer will require a base of 30 hours of labour, plus an additional one hour of labour per additional customer. The hourly cost of a worker is 65 KSh [38]. In the future, additional labour will be required for business development, accounting, partnership development and associated activities. These costs are not currently included in the model because the founders will handle these tasks in the first stages of the program.
- **Soil testing.** One test will be performed per 10 customers; this will allow the team to tailor fertilizer composition to regional nutrient needs, while keeping the cost of testing low. The cost per test is 1,300 Ksh [24].

4.3.3 Profit/Breakeven

Table 4 shows the pricing structure for varying number of customers in two scenarios: break-even and with a 5% profit margin. A small profit margin maintains the goal of operating as a non-profit while insulating ourselves against unforeseen costs. Given that the pilot would involve 10 farmers for one year of service, the team believes that after two to four years of service there will be 100 farmers involved in the program.

Table 4: Pricing structure for the fertilizer service

	Break Even	**5% Profit**

Number of Customers		**100**	**1000**	**100**	**1000**
Cost in Ksh	Annual	5888.92	4260.49	6183.37	4473.51
	Monthly	490.74	355.04	515.28	372.79
Cost in USD	Annual	58.31	42.18	61.23	44.29
	Monthly	4.86	3.52	5.10	3.70

In order to break even with only 100 customers in the early stages of roll out, the monthly cost of the service must be set at 490.74 Ksh ($4.86 USD) per two 50 kg bags of fertilizer, which is the annual need for the average size of a smallhold farm in Kenya; this price will differ by customer depending on the size of their farm. As more customers are gained, the cost of the service is driven down: when 1000 customers partake, the cost of the service is lowered to 355.04 Ksh ($3.52 USD) per month. However, it is not the team's intention to adjust the cost of the service once it has been launched; a pricing structure would be developed and stuck to.

The average Kenyan smallholder farmer’s annual income is $2,527 USD (using 2009 conversion rates), and it is estimated that an annual product cost exceeding 5% of their income will require subsidy. At a customer base of even 100 farms, the monthly cost of the service for the average farm size is $4.86; this is below $10.53 (5% of the average monthly income) and thus is deemed affordable. However, the average income may mask variation; some customers located particularly in low-production regions of the country may have a significantly lower monthly income, and thus this service may exceed what is affordable. In this case, the team will seek ongoing subsidy to decrease the financial burden.

Because affordability for poor smallholder farmers is the goal of this project, the monthly cost of the service will be set to 341 Ksh ($3.38 USD) per month for the average farm size; again, this will differ based upon the size of eazch customer's farm to to differing needs in fertilizer quantities. 15,000 customers would be required to provide this cost while breaking even. This would no doubt take several years to achieve, but it is not unreasonable: 15.9 million Kenyans are smallholder farmers, and can be reached through effective marketing. The monthly cost of 341 Ksh is selected because a value lower than this would not allow the program to break even; at this point, fixed costs are divided across a sufficient number of customers such that they are nearly negligible.

Profiting is not the goal of this enterprise, but a 5% profit margin would help to cover unforeseen costs. If this is the goal, the monthly cost of the service would need to be set to 358 Ksh ($3.55 USD) per month. Though this could potentially decrease affordability to some farmers, the increase may be worthwhile for the sake of Fertify's financial stability.

5 Social Impact

5.1 Mission

The team's mission is to expand access to fertilizer to smallholder farmers in Kenya. Access to fertilizer will improve the yield of their produce, their incomes, and thus their financial resilience.

5.2 Competition

Through research, it was found that there were no other existing organizations or companies which offer the same service as Fertify. That said, there exist companies in Kenya which broadly focus on aspects of increasing access to fertilizer or use of fertilizer. Namely, FarmDrive is a startup which operates in Kenya and focuses on increasing fertilizer access to farmers, whereas WeFarm and Apollo Agriculture provide farmers with advice on farming practices specific to their situation.

WeFarm has been successful at linking farmers with each other by providing answers to approximately 1.5 million questions which farmers have had worldwide [20]. This has allowed farmers to share innovative ways of dealing with climate change and other agricultural challenges with each other, allowing them to produce higher yields. Because WeFarm overlaps only with the SMS information system aspect of Fertify's activities, it is not considered to be in competition with this service. In another example, FarmDrive provides farmers with access to credit and loans as well as information about farming practices using machine learning; because their goal is to increase access to financing for farmers, it is unlikely that FarmDrive will be a source of competition for Fertify.

5.3 Measurement

The 10-customer pilot will allow for precise, qualitative data to be collected and used to improve the service and provide indications as to whether fertilizer usage has a significant positive impact on crop yields. After proof of concept, when scalable operations have been implemented and the number of customers is higher, a thorough RCT should be performed to statistically evaluate the effects of the program on yields, incomes and user satisfaction. For credibility, the RCT would need to be performed with external (academic) partners and include a control group. If the results are decisively positive, the study will provide strong leverage in applying for funding and persuading customers to adopt the service.

In alignment with the mission, data collected from the customers must serve three main purposes:

i. to estimate the effects of fertilizer use on crop yields as accurately as possible

ii. to communicate these estimates to smallholder farmers and external stakeholders in a convincing, honest and transparent way, empowering them to make evidence-based decisions
iii. to find ways in which the business model fails to meet the needs of its customers

Some possible metrics that could help achieve these goals include:

- Percentage change in self-reported crop yields from the year before adoption to the first year of adoption. It is especially interesting to determine the return on investment of fertilizer, i.e., the ratio between how much the farmers' revenue increased and the cost of the fertilizer service. However, since crop yields depend non-linearly on a range of external factors, crop yield changes alone will not constitute robust statistical evidence of the efficacy of fertilizer use.
- Customer retention rates. This metric complements the above, as it evaluates the customer experience of the service as opposed to only the effects of the fertilizer delivered. The decision to remain a customer or not gives insight about how well the offer is tailored to the farmers.
- Qualitative surveys of customers abandoning the service. Through these surveys, aspects of the service that are poorly designed can be brought to our attention. This would in turn allow for iterative business model improvement.

In addition to metrics of the effects of the service on customers, it may be of interest to evaluate how increased fertilizer usage affects long-term soil quality features such as nutrient density and organic carbon levels. This issue is relevant to both farmers and academics. Within time and money constraints, we would happily cooperate with researchers interested in this subject.

6 Conclusions

6.1 Teams Strengths and Weaknesses in Transition to Business

Research suggests that affordability is not enough to increase fertilizer access in these regions; fertilizer must be made *accessible.* This service provides improved accessibility in three aspects:

- **Financial accessibility.** By converting what is traditionally a one-time payment to a year-round subscription, the service makes the cost of buying fertilizer much more manageable for its customers.
- **Geographical accessibility.** The service makes fertilizer available in low-yield regions, and makes sure that the investment is worthwhile even for farmers with atypical soil characteristics.
- **Information accessibility.** By delivering well-timed, highly relevant information on fertilizer usage and market prices, farmers are empowered to make better decisions about their land from day one.

In addition, the product is affordable and designed for the needs of each farmer.

The service has, however, been designed far from the context of use and by a team without personal experience of Africa South of the Sahara, let alone Northeastern Kenya. While relevant information can certainly be found in research and online media, there is a significant risk that the team has failed to account for certain contextual factors. Additionally, the team has no educational background in chemistry of agricultural studies, which would prove useful in designing an efficient fertilizer product. These knowledge gaps are "unknown unknowns" in that they are not design weaknesses at this stage, but risk factors in a future implementation of the service.

The team has several strengths as well which are assets in implementing this service. Firstly, the team's industrial engineering background lends itself to creation and optimization of processes. Additionally, one team member has experience with policy making and analysis; this could be useful when navigating the implementation of the service in collaboration with government organizations. Furthermore, one team member has taken several courses in the field of business during undergrad; this knowledge is useful at creating and iterating upon the service's business plan, as well as creating business processes to ensure operations run smoothly.

6.2 Critical Assumptions

For the service to be successful, the following assumptions must be at least partially true:

- Yield increases as a consequence of fertilizer use must be significant even in arid regions.
- Mass text messages can be sent to participating farmers.
- Fertilizer can be purchased at the government-subsidized rate.

6.3 Most Significant Challenges

After researching the background context and solution space, several challenges remain in designing a successful service. The most likely and significant of these are:

- Obtaining realistic cost estimates & other regional information.
- Obtaining financing for the initial stages of the service implementation.
- Understanding how much potential customers are able and willing to pay for the product.
- Finding and persuading farmers to adopt the service.
- Gaining trust from the farmers.
- Building a positive reputation in the Kenyan agricultural community.
- Barriers of language, culture and bureaucracy.

6.4 Unanswered Questions

- Today, we do not know the extent to which soil test results can be interpolated over spatial and temporal distance, i.e., at how many places and points in time soil test will be necessary. Additionally, we have assumed that information about soil quality is helpful in determining the optimal blend and quantity of fertiliser, but we have found little research on the topic.

- How do we deliver to farms which don't have addresses?
- Can fertilizer be imported and distributed for a lower cost per kilogram than it is currently sold at its government-subsidized cost?
- How geographically dense are smallholder farms in low production regions?
- How much additional labour will be required for business development, accounting, partnership development and associated activities?
- What are the current soil nutrient characteristics, and what are the specific nutrient deficiencies? Can a single application of fertilizer sufficiently address these deficiencies, or are years of application required to rebuild nutrient density in soil?

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