# TABLE OF CONTENTS

1 TECHNOLOGY DESCRIPTION ................................................................. 1

2 SMALLHOLDER FARMER NEEDS BEING ADDRESSED BY THE TECHNOLOGY .......... 3

3 CURRENT STAGE OF MATURITY .......................................................... 5

4 VALUE PROPOSITION FOR THE SMALLHOLDER FARMER ......................... 6

   4.1 Cost-Benefit Analysis for the Smallholder Farmer ........................................ 6
   4.1.1 Cost ........................................................................................................ 6
   4.1.2 Benefits to the Smallholder Farmer .......................................................... 6

   4.2 ROI Modeling and Analysis ................................................................. 6
   4.2.1 Description ............................................................................................. 6
   4.2.2 Arthur D. Little Inc. Return on Investment for Smallholder Farmers Methodology and Approach ................................................................. 6
      A. Develop Baseline Smallholder Farmer Financial Model ................................ 7
      B. Determine Technology-Specific Assumptions ............................................. 9
      C. Calculate Return on Investment ................................................................. 10
   4.2.3 ROI Summary and Conclusions .............................................................. 12

5 MARKET POTENTIAL FOR THE TECHNOLOGY IN SUB-SAHARAN AFRICA ......... 13

   5.1 Market Potential ..................................................................................... 13
   5.1.1 Customer Type ..................................................................................... 13
   5.1.2 Geographic Reach Among the Bill & Melinda Gates Foundation Focus Countries .... 13
   5.1.3 Crops Affected ..................................................................................... 13

6 POTENTIAL BARRIERS TO SUSTAINABLE ADOPTION AND PERFORMANCE ...... 14

   6.1 Cost ........................................................................................................ 14
   6.2 Cultural Acceptance ............................................................................... 14
      6.2.1 Smallholder Farmer Education ............................................................. 14
      6.2.2 Policy Constraints .............................................................................. 14
   6.3 Commercialization ................................................................................. 15
   6.4 Technology Considerations ..................................................................... 15

6.5 Production Challenges ............................................................................ 15
      6.5.1 Local Manufacturing ........................................................................... 15
      6.5.2 Importation ........................................................................................ 16
      6.5.3 Distribution ......................................................................................... 16

7 HOW WOULD INVESTMENT BY THE FOUNDATION HAVE A SUBSTANTIVE IMPACT? .17

   7.1 Product and Infrastructure Improvement .................................................. 18
   7.2 Sustainable Business Model ..................................................................... 18
   7.3 Promotion of Better Farming Practice ...................................................... 18
1 Technology Description

Soil Health Combination Packages are designed to counteract the decreased soil fertility that is characteristic of sub-Saharan Africa. Rather than address soil deficiencies individually, an integrated package provides combinations of fertilizers, seeds, and/or inoculants that support the creation of a healthy soil environment that is conducive to crop growth and productivity.

A number of integrated technologies (combinations of seeds, fertilizers and/or inoculants) for soil fertility management have been developed, tested, and distributed to smallholder farmers in Africa. Examples of these integrated packages include formulations with fertilizers, seeds, and inoculants, but this technology could potentially be expanded to include other crop requirements such as herbicides or pesticides.

Following is an overview of the key components included in four Soil Health Combination Packages developed and tested in sub-Saharan Africa:

<table>
<thead>
<tr>
<th></th>
<th>Seeds</th>
<th>Fertilizer</th>
<th>Inoculant/Gum</th>
<th>Herbicide</th>
<th>Lime</th>
<th>Pictogram Instructions</th>
<th>Sprayer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Universal Starter</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PREP-PAC</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Combi-Pack</td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mini-Pack</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

In 1999, the Universal Starter Pack program was launched in Malawi in order to improve maize production for the smallholder farmer. These 2.5 kg packages contained hybrid seeds and an economically viable, recommended quantity and type of fertilizer sufficient to plant 0.1 ha of land.\(^1\)

The Phosphate Rock Evaluation Project (PREP) at Moi University in Kenya developed the PREP-PAC, which incorporated fertilizers, seeds, and inoculants for use by the smallholder farmer. This product contained 2.0 kg Minjingu phosphate rock, 0.2 kg imported urea, approximately 0.13 kg of nitrogen-fixing legume seeds (cv. Flora, a climbing variety of *Phaseolus vulgaris*), *Rhizobium* inoculants (BIOFIX), gum Arabic seed adhesive (to hold the inoculant on the seed), and lime pellets (to raise the pH of the inoculated seed environment). One packet was designed to replenish the soil fertility of a 25-50 m\(^2\) patch. The theory behind PREP-PAC was to use it as part of a system where rock phosphate and urea were applied to maize for several cropping seasons, and a legume was intercropped to provide residual fixed-nitrogen into the soil through the activity of *Rhizobium* inoculants (Figure 1).\(^3\)

---

1. “Jump-Starting Maize Production in Malawi through Universal Starter Packs”
In the late 1990s, the Monsanto company in South Africa developed the “Combi-Pack”, which included a package of hybrid maize seed, fertilizer, herbicide, and pictogram instructions. The product was designed for use by the smallholder farmer (those who worked anywhere from 0.25-5 hectares of land). Three versions of the Combi-Pack were available, each containing a different type of seed: conventional seed, Roundup Ready (herbicide protection against weed infestation), and YieldGuard (insecticide protection against insects and worms). Farm Inputs Promotions-Africa (FIPS) designed a cheaper mini-Combi-pack, costing only $1 and suitable for 50 m² plot. The mini-Pack contained 1 kg Mavuno fertilizer, a 150g maize hybrid seed pack from Monsanto, a 10g sachet of Monsanto’s Roundup Max granular herbicide, a 1 liter hand-sprayer, and an instruction leaflet. However, this promotional program was abandoned and the product was never commercialized due to high costs and low demand from smallholder farmers.

---

1 Blackie M & Albright K. “Lesson Learning Study of the Farm Inputs Promotions (FIPS) project in Kenya (with a special emphasis on public-private partnerships for input provision and possibilities for regional upscaling).” February, 2005

2 Interview with Paul Seward, FIPS-Africa, October 22, 2009
2 Smallholder Farmer Needs Being Addressed by the Technology

Soil Health Combination Packages address the most basic need of restoring fertility and productivity to sub-Saharan African soil with a single, comprehensive product. Continuous cropping and lack of adequate nutrient inputs has created broad swaths of degraded, unproductive soil in areas of sub-Saharan Africa such as Western Kenya. The agricultural sector accounts for 30% of the Gross Domestic Product (GDP), 70-80% of employment, and is the major source of food, income and raw materials for industries. Approximately 60-75% of the sub-Saharan African Population lives in the rural areas and therefore relies on the land for survival. Developing a technology that can alleviate the depleted soil in these areas is essential to improving quality of life of the smallholder farmer.

Currently, farmers are given broad-based, macro-level recommendations for fertilizer strategies, which are not effective as they primarily focus on optimizing crop yield rather than the efficient use of scarce resources, and nor do they address the unique needs of the soil in different regions. Soil Health Combination Packages, offer the potential benefit of allowing for the development of seed, fertilizer, and inoculant combinations that can address the soil deficiencies unique to different regions of sub-Saharan Africa more specifically.

Another advantage of integrated packages such as PREP-PAC is their small size. Purchasing seeds, fertilizers, inoculants, and other farming resources in bulk is cash-intensive and not feasible for most smallholder farmers. There are additional problems if any or all of the bulk components are defective in some way and do not provide benefits for the crops. Selling small quantities of inputs may have a two-fold positive impact—in the short-term, the risks of failure can be mitigated; over the long-term farmers will have a cheaper alternative to bulk inputs. Integrated packages may also address the long-term issue of affordability of fertilizer solutions for the smallholder farmer since some of the key components may be derived from local resources (i.e. phosphate rock from local mines).

Field trials with integrated packages have shown significant yield improvements. Universal Starter Packs were distributed to 2.8 million smallholder farmers in Malawi in 1998 and 1999. The results indicated that maize production in each of those two years was increased by an average of 125-250 kg per household, representing a 67% yield increase. The Combi-Pack was introduced in combination with no-till farming practice, and resulted in approximately a 250% increase in yield.

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8 “Jump-Starting Maize Production in Malawi through Universal Starter Packs”

Field tests to determine the efficacy of PREP-PAC were completed in a number of farming regions throughout Kenya. One study was conducted from October 2003 to November 2004 on 50 representative farms of smallholder maize-based systems in Eastern Kenya. In the PREP-PAC treatment, rock phosphate and urea were incorporated into the soil, and inoculated tepary bean seed (provided in the PREP-PAC) and maize were immediately sown. Application of PREP-PAC increased maize yield an average of 1.6 tons/ha compared to 0.65 tons/ha (a 146% increase) in unfertilized soil. Other studies in Kenya and Uganda have shown similar benefits.

Although the formulations thus far have consisted of seeds, fertilizers, and inoculants, it is possible that this technology could also be further adapted to address the other needs of smallholder farmers such as weed and pest control.

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3 Current Stage of Maturity

Soil Health Combination Packages are an embryonic technology, where a number of prototypes have been formulated and field-tested, however, currently no significant integrated fertility management packages are being sold to smallholder farmers in sub-Saharan Africa\textsuperscript{11}.

In 1999, scientists, economists and policy makers in Malawi formed the Maize Productivity Task Force to address the food security issues faced by the country. This organization developed the Starter Pack, a seed/fertilizer combination package, and distributed the package free of charge to approximately 2.8 million smallholder farmers in Malawi\textsuperscript{12}. The main donors for this project then began to scale down their support for the Starter Pack and the program was targeted only at the poorest rural farmers (the Targeted Inputs Program). The loss of financial support for the Starter Pack program led to its abandonment, and it was replaced by a government-run input subsidy program whereby smallholder farmers were given coupons to buy fertilizer and seeds\textsuperscript{13}.

PREP-PAC, a comprehensive soil fertility package containing seeds, fertilizer and inoculants, was developed at Moi University in Kenya in 1997. Initially, 42 retailers in four districts in western Kenya were given PREP-PAC free of charge, and the product was sold to farmers at an average price of $0.56. A second pilot study in Kenya was conducted by SACRED Africa, a grassroots developmental organization, was able to provide 500 PREP-PACs to client farmers. From 1999-2003, 5334 PREP-PACs were distributed through six Non-Governmental Organizations (NGOs), two government ministries, and one private seed distributor. Additionally, 420 packages were sent to Uganda for testing by the National Agricultural Research Organization\textsuperscript{14}. However, due to insufficient demand from the farmers PREP-PAC never reached commercialization.

When the Combi-pack was first released, it was too expensive for experimentation by most smallholder farmers (ranging from $35-$52 depending on the seed type used). The mini-Combi-pack was then created in partnership with Monsanto and FIPS-Africa to create a cheaper, smaller version that smallholder farmers could test on their plots at low risk. This program was eventually abandoned and the product was never commercialized due to insufficient demand from smallholder farmers despite the promotion.\textsuperscript{15}

\textsuperscript{11} Interview with Paul Seward, FIPS-Africa, October 22, 2009
\textsuperscript{12} “Jump-starting Maize Production in Malawi Through Universal Starter Packs”
\textsuperscript{15} Interview with Paul Seward, FIPS-Africa
4 Value Proposition for the Smallholder Farmer

4.1 Cost-Benefit Analysis for the Smallholder Farmer (PREP-PAC)

4.1.1 Cost
The purchase price of PREP-PAC was $0.56 for use on a 25 m$^2$ plot\textsuperscript{16}, resulting in a cost of approximately $224/hectare.

4.1.2 Benefits to the Smallholder Farmer
Poor soil conditions and inadequate weed management contribute significantly to reduced crop yields for smallholder farmer, which has a severe negative impact on their income. Field trials have indicated that maize yields can increase by 146% by using PREP-PAC\textsuperscript{17}, since the package provides higher quality seeds, fertilizer, and inoculants which can help to improve plant nutrition and therefore increase yields. This yield increase translates into increased income for the smallholder farmer.

4.2 ROI Modeling and Analysis

4.2.1 Description
The Return on Investment Model and Analysis completed for the ISHA project has been developed specifically at the request of the Bill and Melinda Gates Foundation in order to analyze the potential return on investment (ROI) a range of soil health and plant nutrition technology under consideration by the ISHA project. The analyses and potential returns are developed and detailed from perspective of the smallholder farmer. The models and assumptions have been developed using the same methodology to ensure comparability among specific ISHA technologies in which smallholder farmers may elect to invest.

The models and assumptions are described in detail and could be adapted to the ROI analyses for different groups of smallholder farmers in different regions. The analyses could potentially also be used for other types of technologies aimed at smallholder farmers.

4.2.2 Arthur D. Little Inc. Return on Investment for Smallholder Farmers Methodology and Approach
The Arthur D. Little Inc. Return on Investment Modeling and Analysis methodology is comprised of three key steps:


\textsuperscript{17} Ibid.
A. Develop Baseline Smallholder Farmer Financial Model

B. Determine Technology-Specific Financial Model Assumptions

C. Calculate Return on Investment

Below is a summary of the approach developed and completed by Arthur D. Little Inc. to calculate the Return on Investment from the smallholder farmer perspective for potential new soil health and plant nutrition technologies.

- Estimated net operating profit generated for the smallholder farmer before and after investment in the technology, including detailed revenue enhancements (such as crop yield increase) and changes in cost structure (such as input and labor expenses).
- Identified and quantified the investments required by the smallholder farmer for successful adoption of the technology.
- Developed assumptions to reflect the opportunity costs incurred by the smallholder farmer as a result of investment in the technology.
- Modeled Smallholder Farmer Financial Operating Results Before and After Adopting the New Technology
- Estimated and Evaluated Return on Investment from the Smallholder Farmer Perspective as a Result of the New Technology

A consistent baseline model ensures a common starting reference point and facilitates the review of each technology vis-à-vis the other technologies being analyzed. Specific revisions to the baseline model then result from the analysis and review of each technology vis-à-vis its effect on smallholder farmer financial operating results. The Return on Investment is calculated applying the same approach for each technology.

### A. Develop Baseline Smallholder Farmer Financial Model

Key assumptions for the baseline smallholder farmer are being used among all technologies under consideration to reflect a “typical” smallholder farmer and enable side-by-side review/comparison of the technologies. The key baseline assumptions\(^\text{18}\) are summarized in the table below.

<table>
<thead>
<tr>
<th>Location</th>
<th>Kenya</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Crop</td>
<td>Maize</td>
</tr>
<tr>
<td>Gender</td>
<td>Male or Female</td>
</tr>
<tr>
<td>Size of Cultivated Area</td>
<td>0.5 Hectare</td>
</tr>
<tr>
<td>Yield</td>
<td>12 bags/hectare (90 kg/bag)</td>
</tr>
<tr>
<td>Farmgate Price Paid to Farmer</td>
<td>$25/bag</td>
</tr>
<tr>
<td>Seed Use Rate</td>
<td>20 kg/hectare</td>
</tr>
</tbody>
</table>

\(^{18}\) The key baseline assumptions are based on extensive and detailed review of a wide range of academic journal articles, economic studies, government databases, interviews with project Experts, and primary field research (discussions with smallholder maize farmers, aid workers, and expert stakeholders, such as the East African Grain Council, in Kenya and Ghana in August, 2009).
Seed Cost | $1.25/kg
---|---
Total labor | $100.00/hectare

- **Location:** The ROI model is conducted from the perspective of a smallholder farmer in Kenya.

- **Type of Crop:** Maize is assumed as the model crop being cultivated based on its status as a widely-grown and consumed source of food security and income. Maize represents 21% of all food crops harvested in sub-Saharan Africa\(^{19}\), and the total demand for maize is projected to double in the next 40 years\(^{20}\). In addition, maize has high versatility—the kernels provide food security due to their high content of essential vitamins and minerals and are therefore a staple food for 50% of the sub-Saharan population, while the leaves, stalk and cob are used as animal feed. The kernels are flexible for the farmer since they can be used either for family consumption or as a cash crop for income.\(^{21}\)

- **Gender:** Soil Health Combination Packages can be used by either a male or a female and is not biased towards one or the other.

- **Size of Cultivated Area:** A typical smallholder farmer has a farm size of 2 hectares, of which 25% is used for growing crops resulting in cultivation area of 0.5 hectare.\(^{22}\)

- **Yield:** The typical maize yield is 12 bags/hectare with each bag containing 90 kg of maize kernels. Maize is sold at a price of $25/bag, for total revenue of $150 from a 0.5 hectare plot.\(^{23}\)

- **Seeds:** Seeds are planted at a rate of 20 kg/hectare, and typically cost the farmer $1.25/kg for a total cost of $12.50 to cover a 0.5 hectare plot.\(^{24}\)

- **Total Labor:** Labor can be divided up into seven key tasks, each of which represents a proportion of the total labor estimated at 100 days per hectare.\(^{25}\) The key tasks include:
  - Land Preparation: 18.2 days/hectare
  - Planting: 7.5 days/hectare
  - Fertilizing: 4.4 days/hectare
  - In-crop Weeding: 38.7 days/hectare
  - Harvesting: 24.5 days/hectare

\(^{19}\) Emerging Technologies to Benefit Farmers in sub-Saharan Africa and South Asia.” http://www.nap.edu/catalog/12455.html

\(^{20}\) Crop Production." http://www.fao.org


\(^{22}\) Source of Estimate: ADL synthesis of discussions with Expert Advisors (Jo Anderson, Rob Delve, Saidou Koala, Pieter Pypers, Paul Seward)

\(^{23}\) Source of Estimate: ADL synthesis of discussions with Expert Advisors (EAGC, Mike Robinson, Paul Seward)

\(^{24}\) Source of Estimate: ADL synthesis of discussions with Expert Advisors (Mike Robinson, Paul Seward)

\(^{25}\) First Hand Field Data from Malawi: Augustine Langyintuo, AGRA
Threshing: 6.7 days/hectare

Total Baseline Labor Costs of $50.00 are estimated based on an estimated wage rate of $1.00 (80KSh) per day\textsuperscript{26} for smallholder farmer tasks, and labor requirements to cultivate a 0.5 hectare plot. The resulting labor costs associated with each aspect of crop cultivation are estimated as follows:

- $9.10 for land preparation
- $3.75 for planting
- $2.20 for fertilizing
- $19.35 for weeding
- $12.25 for harvesting
- $3.35 for threshing

From the Baseline assumptions, the Baseline Net Income of the smallholder farmer is calculated. The Baseline Net Income is the result of subtracting the cost of inputs, equipment expenses, and labor from the revenue generated.

Revenue generated from the baseline model is $150 based on the assumption that 6 bags of maize kernels are produced from a 0.5 hectare plot (based on a production rate of 12 bags/hectare) and sold at a price of $25 each.

Baseline Total Expenses of $62.50 are comprised of the following items:

- Seeds ($12.50) and
- Labor ($50)

Baseline Net Income of $87.50 is calculated as follows:

\[
\text{Baseline Revenue} - \text{Baseline Total Expenses} = \text{Baseline Net Income}
\]

$150.00 - $62.50 = $87.50

**B. Determine Technology-Specific Assumptions**

<table>
<thead>
<tr>
<th>Yield</th>
<th>29.5 bags/hectare</th>
</tr>
</thead>
<tbody>
<tr>
<td>PREP-PAC Cost</td>
<td>$224.00/hectare</td>
</tr>
<tr>
<td>Total Labor</td>
<td>$72.78</td>
</tr>
</tbody>
</table>

Following the adoption of integrated fertility management pack technology, certain baseline assumptions are revised to reflect improved yield and increased labor costs.

- **Yield**: Field trials have demonstrated that maize yields can increase by 146\%\textsuperscript{27} with the use of PREP-PAC, to produce 29.54\textsuperscript{28} bags/hectare. In this model, assuming .5

\textsuperscript{26} Source of Estimate: in-depth expert interview with Paul Seward, FIPS-Africa and discussions with representatives from East African Grain Council, Kenya


\textsuperscript{28} In this brief, all numbers have been rounded, while actual values were used for the calculations in the model
hectare, the yield increases from 6 bags to 14.77 bags and generates $369.23 in revenue, up from $150.00.

- **PREP-PAC Cost:** The PREP-PAC was designed for a use on a 25 m$^2$ plot, and cost $0.56. Scaled up to a one hectare plot, the cost is $224.00. It should be noted that the PREP-PAC includes legume seeds and inoculants, which are included as part of an effort to promote intercropping while growing maize and the increased yields that result from using PREP-PAC are partially a result of including legumes and inoculants in the cultivation process.

- **Total Labor:** The yield is assumed to require proportionately more labor time (i.e. an increase in labor time by 146%) for harvesting and threshing, increasing harvesting labor to 60.3 days/hectare from the baseline level of 24.5 days/hectare and threshing labor to 16.5 days/hectare from 6.7 days/hectare. For a 0.5 hectare plot, this corresponds to an increased labor cost of $22.80.

From these new, technology-specific assumptions, the potential new net income of the smallholder farmer (New Technology Net Income) is calculated as follows.

1. The New Technology Revenue as a result of using PREP-PAC is $369.23 based on the assumed yield increase to 14.77 bags for a 0.5 hectare plot multiplied by $25 per bag.

2. New Technology Expenses total $184.78 based on the following data:
   - The cost of purchasing PREP-PAC is $224/hectare. For a 0.5 hectare plot, the farmer pays $112.00. Since the PREP-PAC includes all inputs (seeds, fertilizer, etc.), there is no additional input cost to the farmer when adopting this technology.
   - Labor expense totaling $72.80, which is $22.80 more than the Baseline, as a result of an increase from 15.6 to 38.4 days required for harvesting and threshing a 0.5 hectare plot based on increased yield levels.

New Technology Income is calculated as follows:

\[
\text{New Technology Revenue} - \text{New Technology Expenses} = \text{New Technology Net Income}
\]

\[
$369.23 - $184.80 = $184.43
\]

**Incremental Investment Required**

The Investment Required by the smallholder farmer relative to a growing a single crop using PREP-PAC totals $122.30, based on the sum of the following:

- Net increase in cost of inputs: $99.50
- Net increase/decrease in labor required: $22.80

**C. Calculate Return on Investment**

The Return on Investment as a result of using PREP-PAC is the ratio of the change in net income that results from integrated soil fertility management pack use, less the technology-specific cost of capital, divided by the investment required, as shown below:
Change in Net Income

The change in net income of $96.93 is calculated by subtracting the net income before using PREP-PAC (Baseline Net Income) from the net income resulting from the use of PREP-PAC (New Technology Net Income).

New Technology Net Income – Baseline Net Income = Change in Net Income

$184.43 – $87.50 = $96.93

Technology-Specific Cost of Capital

Given that adoption of PREP-PAC requires a large amount of additional capital on the part of the smallholder farmer, the financial analysis reflects the assumption that very little or no cash flow exists and the smallholder farmer must borrow 100% of the capital needed.

The Kenya Agency for Development of Enterprise and Technology (KADET), a microfinancing institution in Kenya, offers these types of loans at an interest rate of 30%.

In order to implement this technology, the farmer is assumed to get a loan of $99.50 to cover the addition cost over baseline of purchasing PREP-PAC. The $29.85 cost of capital is therefore assumed to equal the interest that the farmer pays on the loan, or:

Cost of Capital = Interest × Capital Needed = 30% × $99.50 = $29.85

Note that it may be very difficult for the model farm to procure this type of loan, as the amount required is disproportionately large relative to the current revenue potential and income level of the farmer and will be most likely be considered very high risk by potential lenders.

Return on Investment

The Return on Investment from the smallholder farmer perspective is calculated as follows:

\[
\text{Return on Investment} = \frac{\text{Change in Net Income} – \text{Cost of Capital}}{\text{Incremental Investment Required}}
\]

\[
\frac{$96.93 – $29.85}{$122.30} = 55\%
\]
### 4.2.3 ROI Summary and Conclusions

<table>
<thead>
<tr>
<th></th>
<th>PREP-PAC</th>
<th>Baseline</th>
<th>New Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenue</td>
<td>$150.00</td>
<td>$369.00</td>
<td></td>
</tr>
<tr>
<td>Inputs</td>
<td>$12.50</td>
<td>$112.00</td>
<td></td>
</tr>
<tr>
<td>Labor</td>
<td>$50.00</td>
<td>$72.78</td>
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<tr>
<td>Total Expenses</td>
<td>$62.50</td>
<td>$184.78</td>
<td></td>
</tr>
<tr>
<td>Net Income</td>
<td>$87.50</td>
<td>$184.22</td>
<td></td>
</tr>
<tr>
<td>Opportunity Cost</td>
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<td></td>
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<td>Incremental Investment</td>
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<td>$122.28</td>
</tr>
<tr>
<td>ROI</td>
<td></td>
<td></td>
<td>55%</td>
</tr>
</tbody>
</table>

Based on the financial modeling and detailed assumptions developed for this analysis, there is a relatively small Return on Investment of 55% for the smallholder farmer relative to PREP-PAC, particularly relative to the extremely high risk reflected in the very high level of incremental investment required by the farmer.

Difficulty in obtaining proper inputs (i.e. seeds, fertilizer, etc.) contributes to reduced crop yields among smallholder farmers in sub-Saharan Africa. Although PREP-PAC has been shown to significantly improve yields, adopting this technology requires that the farmer take out a substantial loan to cover the cost of purchasing the package. The loan represents a significant portion of the smallholder farmer’s existing annual income, making it a very risky lending proposition and most likely limiting the farmer’s ability to pursue this technology at current pricing levels.
5 Market Potential for the Technology in sub-Saharan Africa

5.1 Market Potential

5.1.1 Customer Type

Soil Health Combination Packages are assumed to be used by smallholder farmers.

5.1.2 Geographic Reach Among the Bill & Melinda Gates Foundation Focus Countries

Soil Health Combination Packages have the potential to reach all of the Bill & Melinda Gates Foundation Focus Countries. However, soil characteristics in different regions of sub-Saharan Africa can vary widely. For example, a combination package using Minjingju rock phosphate as a form of phosphate fertilizer has been shown to be most effective on the Acrisol, Ferralsol, and Acrisol-Ferralsol complex soils that form on acid igneous rock, which are known to occupy approximately 400,000 ha in western Kenya. Therefore, it will be necessary to make packages that contain inputs specifically tailored for the geographic region in which they will be used.

5.1.3 Crops Affected

PREP-PAC was designed to foster the productivity of smallholder maize-legume based intercropping systems. Inoculated bean seed and maize seeds were used with the product during the pilot projects. The potential use of PREP-PAC for other crops is still under study. The Universal Starter Pack was a formulation consisting of hybrid maize seed and the appropriate fertilizer, but it is conceivable that the concept could be expanded to include seeds of other crops as well. Other fertilizer-only formulations could potentially be used on any crop, and the concentrations of nutrients could be adjusted to deliver the appropriate amount for optimal yield.

6 Potential Barriers to Sustainable Adoption and Performance

6.1 Cost
The extremely high cost of previously-developed and tested Soil Health Combination Packages is a potentially significant barrier to adoption of this technology. The Monsanto Combi-Pack prices ranged from $32-$52, and farmers interviewed about PREP-PAC indicated that the price of the small promotional package was too high. Scaling up the cost of the original PREP-PAC indicates that a package to cover a 0.5 hectare plot would be $112, which totals more than a smallholder farmer’s yearly net income of $87.50 using baseline assumptions. This is likely to be perceived as an extremely high risk investment by most smallholder farmers.

The farmer will be required to take out a very large loan in order to invest in this technology for the scale of a small farm and therefore presents a significant barrier to adoption of the technology, as it is unlikely that the farmer will be able to obtain the capital required to invest in the technology.

6.2 Cultural Acceptance

6.2.1 Smallholder Farmer Education
Although the high cost poses a significant barrier, the complexity of using the technology is an additional and significant constraint to its widespread adoption. When PREP-PAC was first formulated, field tests were done in western Kenya to demonstrate its potential benefits for crop yield. One significant issue raised by the farmers was the complexity of the product’s instructions. Unfortunately, simplifying the product and its use is difficult due to the specific requirements associated with appropriate timing and environmental conditions for application of the multiple components that comprise the package. Development of integrated packages similar to PREP-PAC is likely to present similar difficulties for smallholder farmers, which could potentially pose another significant barrier to successful widespread adoption.

6.2.2 Policy Constraints
Significant regulatory approval processes (which would vary from country to country) are hurdles for market growth. A typical process includes registering with the appropriate government agency, and supplying samples for testing. However, bureaucracy and some corruption may slow down the process.

31 Ibid.
6.3 Commercialization

Sustainable, widespread adoption of this technology will likely require significant private sector involvement to produce an effective, usable, cost-effective commercial product. Currently, most private sector players specialize in one component of the integrated packages (i.e. seeds, fertilizer, etc.). However, there are no companies in Africa producing all of the necessary inputs to create a Soil Health Combination Package.

Meridian and ADL are aware of investments in the promotion of Integrated Soil Fertility Management practices among smallholder farmers. These efforts would likely increase the demand for inputs that could be combined in integrated packages. However, it may be likely that local agri-dealers could stock the required inputs and sell them individually (not in packages). Further work would be needed to build the business case for the creation of integrated packages vs. sale of the individual components separately.

6.4 Technology Considerations

Certain environmental conditions inherent to sub-Saharan Africa may pose a risk to the viability of Soil Health Combination Packages.

A package that uses Minjingu rock phosphate will have constraints based on soil pH. Generally, rock phosphate requires acidic conditions to dissolve and become available to the plant (for Minjingu pH<5.5 is optimal), however soils below pH 5.2 are conducive to aluminum (Al) solubility and there is a risk of toxic Al$^{3+}$ cations that significantly reducing crop performance. This level of soil acidity also increases the sorbtion of phosphate ions by iron and aluminum oxides and hydroxides, reducing their availability$^{32}$.

Additionally, inoculants such as Rhizobium quickly lose viability if they are not stored in a sterile, temperature controlled environment. Once in the soil, the high temperatures and soil acidity may also reduce the effectiveness of bacterial inoculants$^{33}$.

6.5 Production Challenges

Production of Soil Health Combination Packages could be done locally or packages could be imported, however both avenues have significant technical challenges related to them. Distribution of these packages also poses an additional challenge.

6.5.1 Local Manufacturing

Mass production of coated seeds will require manufacturing facilities equipped with the proper machinery to organize small quantities of inputs (seeds, fertilizers) into small packages that can be distributed to farmers. There are also challenges associated with certain inputs used to produce these integrated packages. For example, the urea used for a nitrogen source in PREP-PAC was

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not locally available and had to be imported. In addition, inoculants must be grown in a laboratory facility and subsequently stored in a temperature controlled, sterile environment to ensure that the inoculant remains viable.

6.5.2 Importation

Importation of Soil Health Combination Packages into Africa will likely be expensive. In addition, packages that include inoculants must be kept cold and sterile throughout the entire journey. However, Meridian and ADL are aware of technological developments to create non-refrigerated inoculants, which could potentially reduce the cost associated with transportation and distribution of inoculants.

6.5.3 Distribution

The majority of smallholder farmers live in remote, rural areas of sub-Saharan Africa which often lack proper infrastructure for the transport of goods. Therefore, both local production and importation of Soil Health Combination Packages will likely be difficult and expensive to distribute to the smallholder farmer. Local production will also be challenging and expensive if raw material needs to be shipped to manufacturing sites.

However, we are aware of a number of initiatives to strengthen rural agro dealer networks in SSA, for instance AGRA’s Agro-Dealer Development Program, which is working with numerous grantees in SSA to strengthen agro dealer networks. If an affordable and robust Soil Health Combination Package could be created, a possible approach to facilitate distribution of these packages could be by partnering with private sector manufacturers of the package and agro dealer distribution networks.

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35 Junior PIFJ, et al. “Polymers as new carriers for rhizobium inoculant formulations.” EmbrapaAgrobiologica, Rio de Janeiro (Contact: Bob Broddey, bob@cnpab.embrapa.br)
7 How Would Investment by the Foundation Have a Substantive Impact?

In this section are initial ideas on opportunities for strategic foundation investment to help create long-term sustainable access to soil health and plant nutrition technologies for smallholder farmers. Most of the technologies reviewed by the ISHA project are already on the market, but may not be generally accessible to smallholder farmers. The strategic opportunities for the foundation may, therefore, be focused on helping to create or adapt business models, improve market conditions, modify technologies or support targeted technology innovations, or address manufacturing and distribution challenges in order to enable long-term sustainable access by smallholder farmers to these technologies. The opportunities, generally, assume a private-sector driven strategy.

The theory behind PREP-PAC was to design a package that would address all of soil nutrient deficiencies and other issues that contributed to low crop yield. The product was designed by academics and university technicians, who did not always have the proper business insight to make PREP-PAC simple to use, accessible, and affordable. The inputs were purchased from retailers rather than wholesalers, making the input costs very high. In addition, the production efficiency was low since the packages were assembled by part-time students and technicians rather than full-time, supervised employees. In addition to the high costs, the product was far too complex for the smallholder farmer to use, resulting in a lack of demand and subsequently no incentive for private sector involvement in commercialization.  

Based on our review of Soil Health Combination Packages, there may be a number of “high risk, high return” opportunities for the Bill & Melinda Gates Foundation to improve the usefulness of Soil Health Combination Packages for smallholder farmers, including:

- **Product and Infrastructure Improvement.** Create a package that is both cost-effective to produce (and therefore less expensive for the smallholder farmer) and easy to use. Additionally, a strategy to engage private sector companies to supply the necessary inputs for the packages will have to be developed.

- **Sustainable Business Model.** Support the development of sustainable business models. Experiences in SSA appear to indicate that public or not-for-profit organizations play an important role in developing activities to educate and inform smallholder farmers on the effects of various inputs on their crop productivity. Private sector companies are unlikely to invest in such activities. However, a more sustainable model is needed that involves manufacturers in supporting the work by public and not-for-profit organizations on an ongoing basis (perhaps through a royalty structure for “promotion” work done by NGOs, which ultimately benefits the private sector company).

- **Promotion of Better Farming Practice.** In many cases, smallholder farmers will likely not invest in inputs unless they have observed the benefits and concerns over impact on crops, soils, and health are addressed. Interim activities to educate and inform smallholder farmers are likely needed if smallholder farmers are to invest in fertilizers.

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7.1 Product and Infrastructure Improvement

Bringing a commercialized Soil Health Combination Package to smallholder farmers in sub-Saharan Africa will first and foremost require investment in laboratory research that leverages the experiences with PREP-PAC to develop a more successful product. The Foundation could use its network of contacts to support University research as well as bring in other advisors that would have business insight as well as understand the perspective of the smallholder farmer to create a package that is both cost-effective to produce (and therefore less expensive for the smallholder farmer) and easy to use.

In addition, an approach for engaging private sector companies to supply the necessary inputs for the packages will have to be developed. Currently, private sector companies specialize in one aspect of the inputs that make up these integrated packages (seeds, fertilizers, etc.). It will be necessary to support the development of a company, or support partnerships between multiple companies to bring together all the necessary inputs for Soil Health Combination Packages.

Building on – or as part of – product research and development, the Foundation could explore adaptation of the packages beyond seeds, fertilizers, and inoculants to include inputs that address other needs of smallholder farmers such as weed and pest control. Developing the “ideal” package that provides inputs that meet farmers’ needs, is not overly complicated, and is highly affordable could be a key next step in developing a product that would benefit smallholder farmers.

7.2 Sustainable Business Model

Experiences in SSA appear to indicate that public or not-for-profit organizations play a key role in developing such demonstrations to educate and inform smallholder farmers on the effects of various inputs on their crop productivity. Private sector companies are unlikely to invest in such activities. In order to increase adoption of Soil Health Combination Packages by smallholder farmers, demonstrations are probably an important tool, but may not be sufficient. Once an effective approach is developed to encourage the adoption of the technology (see below), a sustainable model is needed that involves manufacturers in supporting the work by public and not-for-profit organizations on an ongoing basis (perhaps through a royalty structure for “promotion” work done by NGOs, which ultimately benefits the private sector company).

During this time, additional investment and efforts would be necessary to establish strategies to support the long-term availability of the product, likely through partnership with the private sector, and ensure that it can be produced and distributed in a cost-effective manner in order to keep prices low for the smallholder farmers. Specifically, there would be investment required to create a private sector company, or forge partnerships between multiple companies, that would be able to bring together all of the necessary components to create an Soil Health Combination Package. The BMGF would most likely also integrate development of an exit strategy to ensure that Soil Health Combination Packages will continue to be accessible after the Foundation is no longer engaged or financially supporting the initiative.

7.3 Promotion of Better Farming Practice

Currently, many farmers are reluctant to use fertilizers due to uncertainty in their profitability (return
on their investment)\textsuperscript{37}. Most likely, this will also be the case for Soil Health Combination Packages. The Foundation could promote pilot studies that demonstrate the benefits of using Soil Health Combination Packages in order to ensure that it reaches as many farmers as possible. Demonstration of significant yield increases of staple crops with the use of Soil Health Combination Packages is important in order to convince smallholder farmers that investing a portion of their often small incomes in Soil Health Combination Packages is worthwhile. However, considering the experience FIPS-Africa encountered, which resulted in their decision to abandon the technology, demonstration projects alone may not be sufficient to convince smallholder farmers to adopt the technology. Investment by the Foundation could focus on developing an effective private-sector driven approach to access and adoption of the technology.

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\textsuperscript{37} Mwangi W. "Low Use of Fertilizers and Low Productivity in sub-Saharan Africa." NRG Paper 96-06. CIMMYT. 1996