11-2015

Sistema Bibolsa: Commercialization of Biol Report

Paul David

Elizabeth Sherwin

Miller Center
for Social Entrepreneurship

FOOD & AGRIBUSINESS INSTITUTE

SISTEMA BIOBOLSA®
NO HAY DESECHOS, SOLO RECURSOS

Commercialization of Biol

Elizabeth Sherwin and Paul David
November 2015

Santa Clara University
www.scu.edu/MillerCenter

Commercialization of Biol

Prepared for: Sistema Biobolsa

Prepared by: Elizabeth Sherwin and Paul David

November 2015

EXECUTIVE SUMMARY

Opportunity

Mexican smallholder farmers currently spend a significant portion of their incomes on chemical fertilizers derived from fossil fuels. Sistema Biobolsa reimagines waste as a resource by converting manure into biogas and biofertilizer, allowing its clients to cut costs and to farm in a more sustainable manner. The excess production of this biofertilizer, called biol, presents an opportunity for Sistema Biobolsa to reach more smallholder farmers and broaden its socio-environmental impact. If measures are taken to improve the nutrient content of biol, a commercialization model could offer even more farmers a low-cost, natural fertilizer and the opportunity for more sustainable livelihoods.

Research Activities

Over the past nine months, our team conducted research to evaluate the business potential of Sistema Biobolsa's biol fertilizer. During our two months in the field, we collected nearly 100 surveys from farmers and key stakeholders to understand the size of the opportunities for both producers and potential consumers in the biol market, as well as to identify potential barriers to success.

Key Findings

First, all farmers we talked to about biol said that they would need to see it work and know the chemical composition before they would be comfortable selling or buying it. Second, the commercial viability of biol is dramatically diminished by the fact that most samples only have a 1% nitrogen composition, which means that crops will require large amounts per hectare to fertilize properly. Third, most farmers are uneducated about necessary biol practices, which results in improper storage and application techniques.

Deliverables

This report encapsulates our research process, key opportunities, and challenges identified in the field. We recommend ways for Sistema Biobolsa to successfully pilot a biol sales model, focusing on best practices for biol storage, treatment, quality control, distribution, and application. The report is accompanied by a distribution decision tool to guide day-to-day decision-making by technicians and to serve as a resource for long-term planning by the Sistema Biobolsa team. This tool will allow the executive team to adjust the unit economics of the business plan, and each day technicians can check that the key assumptions are accurate, enter the starting locations, and see maps of all client locations that fall within the radius that the model deems financially feasible.

Recommendations

We recommend that Sistema Biobolsa improve farmer education, specifically by encouraging users to feed their digesters more often to increase biol production, as well as teaching them to cover biol with a 10-20cm layer of leftover materials such as corn husks to prevent ammonia volatilization. To prevent nutrient loss, it is important that biol be better incorporated into the soil, and this can be accomplished through either educating farmers about more effective application techniques or establishing an application service run by Sistema Biobolsa. Most importantly, Sistema Biobolsa must conduct more tests to understand the true nutrient content of biol before it can become a competitive commercial product.

INTRODUCTION

Sistema Biobolsa's biodigesters, termed biobolsas, improve the livelihoods of small and medium farmers and provide alternatives to costly and unsustainable agricultural practices. Through collecting and inputting animal waste into their biobolsas, users receive biogas for cooking and heating, as well as biol, the liquid digestate byproduct of the anaerobic digestion process. Biol represents a valuable resource to users, as its nutrient content makes it a good natural fertilizer. Biol allows users to save money spent on fertilizers and provides an environmentally sustainable alternative to chemical fertilizers.

There is great potential for the commercialization of biol, as many biobolsa owners are producing biol that exceeds their needs. The goal of our research was to identify the opportunities and challenges of commercializing excess biol, as well as make recommendations for more efficient use of biol by both biobolsa owners and potential biol buyers. Once the challenges are addressed, biol commercialization will allow Sistema Biobolsa to broaden their social impact and improve the lives of even more farmers.

This research project represents a collaborative effort between Sistema Biobolsa and the Miller Center for Social Entrepreneurship at Santa Clara University.

TABLE OF CONTENTS

Agro-Ecological Description of Biol.....6
Farmer Perceptions of Biol.....7
Biobolsa Owners.....7
Potential Buyers.....8
Optimizing Biol Nutrient Content.....9
Storage.....9
Treatment.....10
Quality Control.....12
Application.....12
Biol Distribution.....14
Agrochemical Shops.....14
Sistema Biobolsa Distribution.....14
Distribution Decision Tool.....16
Recommendations.....17
Appendices.....19
Appendix A: Background: Collective Farmer Profile.....19
Appendix B: References.....22
Appendix C: Digestate Treatment Methods.....24
Appendix D: Methods.....24
Appendix E: Research Limitations.....25
Appendix F: Interview Guides.....26
Appendix G: Data Collection Sheet.....30

AGRO-ECOLOGICAL DESCRIPTION OF BIOL

Biol is currently an underutilized resource for several reasons. First, because the value of biol is unknown, users do not know how much biol to apply to their crops, often resulting in wasted biol and over application. Second, many biobolsa owners do not apply biol due to the effort involved in application. Third, important nutrients in biol are lost due to inefficient storage and application processes. There is a need to improve the nutrient content of biol, measure its value, and educate users in order to maximize biol utilization and effectiveness.

Unlike commercial chemical fertilizers with standardized known concentrations, the content and value of biol is invisible and variable. Many factors contribute to biol variation, including the type of animal waste and the diet of that animal, waste to water ratio of input, and biol storage. Additionally, application techniques, soil composition, and climate affect the result of biol on various crops. Although not every step of the biol production and application process can be standardized, especially for Mexican smallholder famers, this study identifies the processes that can be better monitored and controlled to create a more standard biol product.

FARMER PERCEPTIONS OF BIOL

Biobolsa Owners

Figure 1 illustrates biol usage among the 56 biobolsa owners surveyed. Many farmers currently use as much biol as they think they need and give away the rest. There is a small group, about 11%, that does not even collect biol as it comes out of the digester, mainly due to the labor involved in application. Nearly all farmers are unsure of the value of biol. This leads some to add all of their biol to their fields, while others give it away for free or do not collect it at all. Farmers base their opinions of biol off of their own experiences. Those that have seen better crop yields after applying biol swear by its efficiency, while others who did not see great results stick with chemical fertilizers.

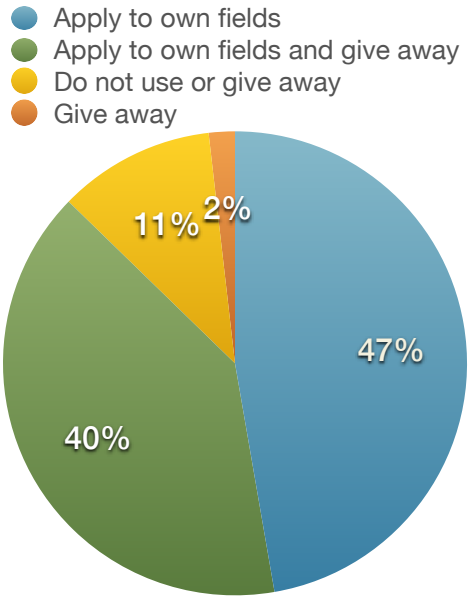


Figure 1. Biobolsa owners, "What do you do with your biol? (n=55)

Among the 56 biobolsa owners surveyed, there is a consistent desire to know more about biol: how much water they should add to their digesters, how much biol should be applied to their fields, and the chemical composition of biol. Just like any other farmer, these biobolsa owners are results driven: they want to know the value of biol and that it will produce good results on their crops.

While some farmers consider biol equal or better than chemical fertilizers, there is a general perception of biol as cheap because it is a byproduct of manure. We asked biobolsa owners if they would be interested in selling biol in the future, understanding that their answers are only speculative. Most said they would be interested in selling, especially if a biol collection and transportation service were provided. Most could not give an estimate for how much they would like to be paid for biol, as they believe understanding the chemical composition and

value of biol determines its price. They also remarked that, before recommending biol to friends and neighbors, they would need to see the results of biol on their own fields and understand its value.

Potential Buyers

We asked the potential buyers surveyed if they had an interest in buying biol in the future. All potential buyers surveyed reported that the most important factor in determining whether they would purchase and use biol is the results that it gives. Eighty-two percent of potential buyers reported interest in purchasing biol, but this interest was conditional. All said they would need to see good results in order to commit to biol. They are only interested in purchasing biol if it produces equal or better results on their crops compared to the fertilizers they currently use. These results can be observed in a number of ways. Most expressed interest in trying out biol on their own crops and seeing for themselves. But in order to even take this initial step of testing biol on their own fields, many would need to first know the exact nutrient content of biol. Some would also need to be convinced, either through neighbor recommendations or Sistema Biobolsa field experiments, that biol produces good results before they try it on their own land.

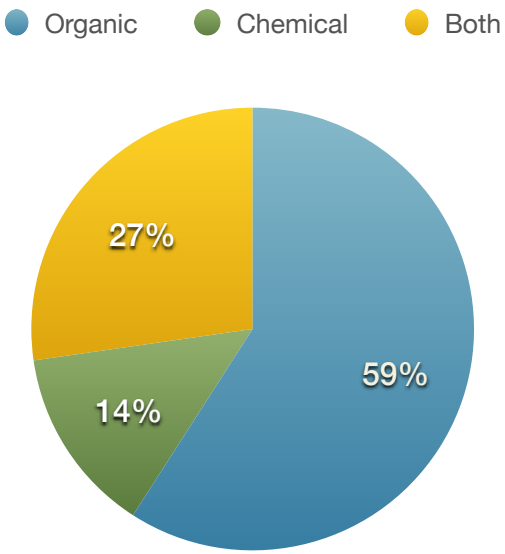


Figure 2. Potential buyers, "Do you think organic or chemical is better? (n=22)

Although 90% of potential buyers surveyed use chemical fertilizers, when asked which is better, organic or chemical, the majority chose organic, as shown in Figure 2. Although most use chemical fertilizers, and many have never even used organic, they believe chemicals are bad and can be unhealthy, so replacing them with organic would be ideal. Therefore, there is great opportunity for an effective, low cost natural fertilizer.

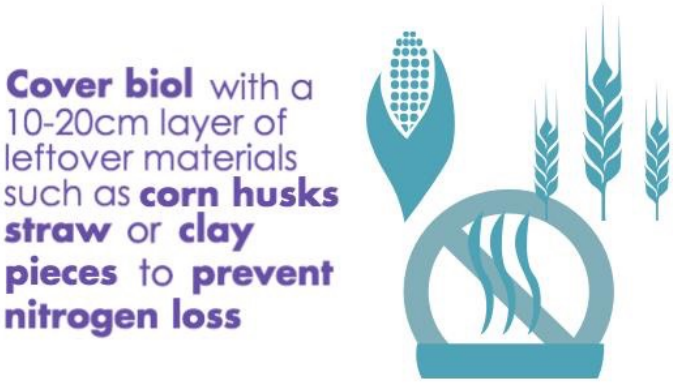
We asked potential buyers what they would be willing to pay for biol, and many were unable to give

us an answer. They reported a need to first understand how biol compares to the products they currently use. Only after knowing the value of biol can they give it a price. However, several expressed a desire to pay less for biol compared to chemical fertilizer, even if biol works the same or better than these chemicals. Their reasoning is twofold: first, liquid fertilizer is more difficult to transport and apply compared to solid granules, so if they are going to make the extra effort to apply biol, it should be less expensive. Second, biol comes from animal waste and is therefore expected to be cheap; it should not have the same kind of expense as a manufactured chemical product.

OPTIMIZING BIOL NUTRIENT CONTENT

Biol Storage

Educating farmers to store their biol correctly will prevent nitrogen loss and greatly improve the effectiveness of biol on the soil. Nitrogen is the most important nutrient in biol, making biol valuable and competitive with chemical fertilizers. Therefore, nitrogen loss is detrimental to the value of biol and decreases its results. Upon leaving the anaerobic environment of the digester and being exposed to the air, ammonia volatilization will begin to occur. Several studies have been done on this topic, and all cite the detrimental effects of ammonia volatilization on the effectiveness of digestate (Lukehurst, Frost, & Al Seadi, 2010; Nkoa, 2013). For example, due to ammonia loss Cavanagh and others found that nitrogen in biol was two times less effective than mineral fertilizer (Warnars & Oppenoorth, 2014).



While industrial biodigester plants in Europe often cover digestate with an airtight membrane or storage bag to prevent nitrogen loss, this practice is not appropriate for smallholder farmers in Mexico (Lukehurst, Frost, & Al Seadi, 2010). Instead, digestate can be covered with other, less expensive

and more readily accessible materials. For example, a 10-20cm layer of leftover products such as straw, clay pebbles, or plastic pieces can create a semipermeable membrane over biol to reduce ammonia volatilization (Börjesson & Berglund, 2007; Lukehurst, Frost, & Al Seadi, 2010).

Another option may be to cover biol with a thin layer of surfactant, a hydrocarbon chain that alters the liquid surface tension, to prevent ammonia loss. This technique has not been applied specifically to digestate, but rather to prevent evaporation in rivers and reservoirs, where it has been shown to reduce water loss by 60-70%. Currently research is being done to produce a less expensive surfactant, for example through the use of microorganisms, many of which are known to produce secretions similar to synthetic surfactants (Hightower & Brown, 2004). More research must be done on the effectiveness of these surfactants and to ensure that they do not interact with nitrogen, but they should be kept in mind as a future possibility for biol.

Biol Treatment

In Europe, the first step of biol treatment is usually separation of the solid and liquid portions. Several different machines may be used, such as a belt press, sieve drum, screw press, and various types of centrifuges. This type of machinery is not accessible to Mexican farmers, although if a biol collection center is established, investing in certain treatment equipment should be explored. There are also more affordable, non-machine separation methods, such as filtering digestate through geotextile tubes (Lukehurst, Frost, & Al Seadi, 2010). Several studies have been conducted in Germany and other parts of Europe to test various filtration and separation methods. Each technique is more or less suitable in a given situation, depending on the resources available and the end goal for the digestate (Chiumenti, da Borso, Teri, Chiumenti, & Piaia, 2013; Al Seadi & Lukehurst, 2012).

Some of the benefits of separating the liquid and solid portions of digestate include reducing liquid storage volume, preventing the solid portion from clogging liquid application machinery, and increasing nitrogen uptake by the plants when liquid is applied (Lukehurst, Frost, & Al Seadi, 2010). However, when the liquid and solid are separated, most of the nitrogen and potassium will remain in the liquid, while the phosphorus will stay in the solid. Therefore

separating the liquid and solid portions of digestate reduces the nutrient content of liquid biol (Pell Frischmann, 2012).

Digestate treatment is a growing practice in Europe and around the world. Various studies have examined treatment both pre and post-digestion. These treatments can be grouped into four main categories. Physical treatments, which mainly involve filtration, thermal treatments to dry digestate, biological treatments such as composting, and chemical treatments such as ammonia recovery. See table 1 in Appendix C for more examples of treatment methods (Pell Frischmann, 2012).

Physical and thermal treatments may not be feasible options for biol. Separation of digestate is typically done as a prerequisite to other thermal and biological treatments, and therefore separation will not be useful to biol unless more steps are taken to treat it. Thermal treatments typically require a lot of machinery and energy and are therefore not affordable or accessible to Mexican smallholder farmers. Furthermore, thermal methods are focused on drying solid matter and are more suitable for thicker digestates (Pell Frischmann, 2012).

Chemical treatments are a common way to pull existing nutrients out of digestate. Struvite precipitation is a common treatment in which struvite (magnesium ammonium phosphate) is extracted from the digestate, usually through adjusting the pH and adding magnesium (Pell Frischmann, 2012). Struvite precipitation is expensive because of the magnesium and phosphorous additives required. However, researchers are currently exploring variations of struvite precipitation using less expensive magnesium and phosphorus additives, such as seawater bittern and bone meal (Sicilliano & De Rosa, 2013).

Biological methods may be the most feasible type of biol of treatment. Co-composting digestate with green waste or woodchips is one method of increasing nutrient content. While the digestate offers nitrogen, phosphorous, and other nutrients, the raw materials improve the carbon to nitrogen ratio. By composting the digestate with other materials, more ammonia is converted to nitrate, a more stable form of nitrogen that will improve plant nitrogen uptake (Sicilliano & De Rosa, 2013).

Quality Control

The two most important factors in digestate quality are the feedstock inputted into the digester and the anaerobic digestion process itself. As farmers have no control over the actual anaerobic digestion process within the biodigester, feedstock quality is the key area of importance. The animal manure must be free from impurities before entering the digester. Farmers should keep animal waste away from chemicals and not input waste that has been exposed to any chemicals. Farmers must not input waste from sick animals, especially if they are taking antibiotics. Visible impurities such as clumps of straw, stones, glass, or wood should be manually removed from the waste before input (Al Seadi & Lukehurst, 2012).

Additionally, it is important to put measures in place to ensure that biol producers do not dilute their biol with water before selling. One simple quality control method would be to create a color strip of multiple shades of biol, showing what normal versus diluted biol looks like. Sistema Biobolsa would initially create this color strip by taking several samples of diluted and undiluted biol. Once the strip is created, technicians can simply scoop up a small sample of biol in a clear tube and verify that it is the correct shade.

Biol Application

Application is of major importance in the ultimate effectiveness of biol on soil and plants, as certain application techniques reduce nitrogen retention in the soil. Just as ammonia volatilization is a concern if biol is left uncovered, nitrogen loss can continue once applied to the soil. Therefore, improving farmer education and application techniques will likely improve their results.

Biobolsa owners are currently using four main biol application techniques. First, the most common practice is to apply biol manually using a 20-liter bucket. Farmers simply fill a bucket with biol and walk along their crops, splashing biol onto the crops and the surrounding soil either directly from the bucket or using a smaller cup. Second, some will use their backpack sprayer to shower their plants and land with biol. Third, some mix their biol with water and pour it on their irrigation canals at the top of their field, allowing the biol-water mixture to flow down the canal with gravity. Lastly, some biobolsa owners will put their biol in a tank in the back of a

truck and spray biol out of a hose or tube as they drive along their field. It is rare for farmers to have the tools to employ this last technique, so some will employ Sistema Biobolsa for this service using the company's truck and tank.

It is widely accepted that immediate incorporation of digestate into the soil limits nitrogen loss and therefore improves the effects of digestate on the soil (Lukehurst, Frost, & Al Seadi, 2010; Nkoa, 2013; Al Seadi, 2001). Injection is the main method for accomplishing this incorporation, however, due to the high cost of injection equipment and the damage it can cause to the crops, this method is not highly feasible for smallholder farmers in Mexico (Nkoa, 2014). According to the literature, the second best option is the trailing shoe method because, similar to injection, the machinery makes a slit in the soil before pouring out the fertilizer, preventing ammonia loss (Lukehurst, Frost, & Al Seadi, 2010).

The machinery needed for either injection or trailing shoe application of digestate is not affordable or feasible for smallholder Mexican farmers. However, educating biol users on a few key practices may help reduce nitrogen loss. First, as faster incorporation into the soil is vital to retention of nitrogen and other nutrients, we recommend that farmers pour biol onto the soil surrounding their crops rather than using a backpack sprayer. Spraying biol from up high causes more of the biol to go to waste, as the liquid that lands on the plant leaves does not get absorbed. Second, nitrogen retention will be higher during the growing seasons. Although some farmers may choose to apply biol year-round, the literature suggests that it is best to apply digestate during the spring and summer. During the fall and winter more nitrogen leaching will occur, and biol will therefore be less effective. It is recommended to not apply biol during seasons of heavy rainfall, as more of it will be washed away (Lukehurst, Frost, & Al Seadi, 2010). Additionally, stirring of biol right before application is important to improve the consistency of nutrients throughout the soil. However, stirring can also contribute to nitrogen emissions and therefore should only be done at the moment of application (Al Seadi & Lukehurst, 2012).

Based on our surveys with Biobolsa owners, biol application represents the largest reason for biol underutilization. Farmers do not have the time and resources to continually collect biol and apply it to their crops. There is a great opportunity, especially as a part of a pilot biol sales

model, to offer this service to farmers. Not only would Sistema Biobolsa promote biol use by helping with application, but they could also improve application techniques. By investing in the right equipment, Sistema Biobolsa could inject biol into the soil rather than spraying it, improving nitrogen retention.

BIOL DISTRIBUTION

Biobolsa owners and potential buyers of biol share concerns about the transportation of biol. While over 50% of biol producers and over 70% of potential buyers surveyed have access to a truck, transporting biol is very labor intensive and costly, especially for a product with an unknown value. Here we explore two possible options for biol distribution.

Agrochemical Shop Sales

Currently, all potential biol buyers purchase chemical fertilizers from local agrochemical houses, located not more than five kilometers from their homes. Agrochemical shops could provide an already established, local market for biol. Many of these stores are only making a five percent margin on the sale of chemical fertilizers, so if biol offers a higher margin it would be especially appealing. But, just like the biol producers and potential buyers, workers at the agrochemical houses we surveyed were results driven. Biol must be an effective fertilizer worthy of recommending to customers. Most reported that an in-house engineer must first test out biol before accepting it as a new product.

Limited available space in agrochemical houses may pose a problem. These are one-room shops with little extra space. Considering the amount of biol currently recommended per hectare, right now these houses could barely fit enough biol for one customer. Until biol is further tested and options to improve the nutrient content of biol are explored, agrochemical shops are not a feasible method for distribution. However, they are an important potential partner should the value of biol be better understood and the volume needed per hectare be reduced.

Sistema Biobolsa Distribution

Seventy-two percent of potential buyers have access to a truck and said they would most likely visit a collection center or other pick-up location to purchase biol. However, considering the

accessibility of chemical fertilizers at agrochemical houses, a biol collection center would need to be local in order to compete. Additionally, access to a truck alone is not enough. Most farmers do not possess large transport containers nor do they have adequate equipment for biol application.

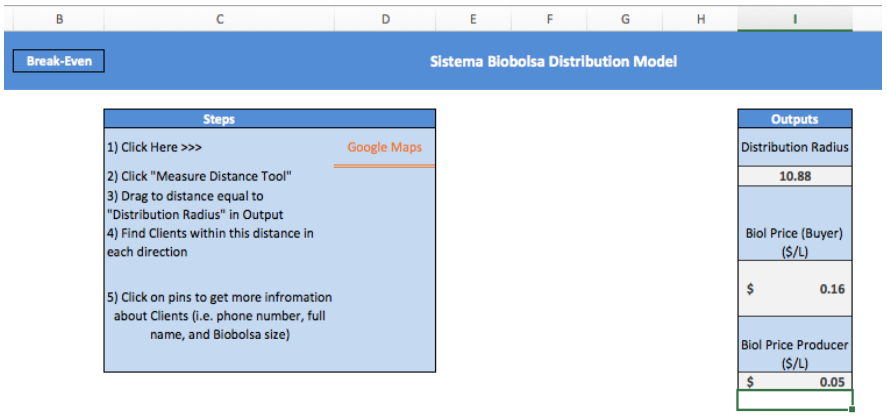
Accordingly, Sistema Biobolsa could operate a program of biol distribution to initiate the biol market. Sistema Biobolsa already owns most of the equipment needed to collect and transport biol. By driving to biobolsa owners' houses and collecting biol in the 1000-liter tank in the back of their truck, Sistema Biobolsa could save biol producers the time and hassle of transporting biol to a collection center themselves. More biobolsa owners will sell their biol if someone comes and picks it up compared to if they have to transport it on their own. This transportation service can be factored into the price producers are paid for their biol.

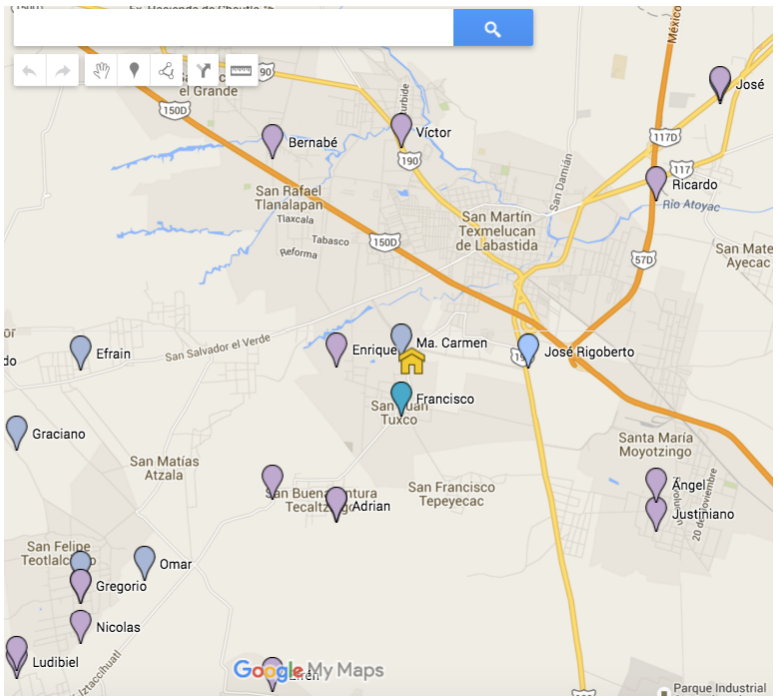
At some point in the future this distribution service could be transferred to another enterprise, creating a distribution system independent from Sistema Biobolsa. However, we believe it is in the best interests of Sistema Biobolsa and its clients to initiate this distribution program. Sistema Biobolsa technicians already know the locations of their clients, who trust them. This relationship will facilitate biol pick-up and encourage more producers to participate, as they are more likely to sell biol to someone they know and trust. Additionally, the large space behind the Sistema Biobolsa field office offers a convenient, no-cost collection center for biol. In an independent distribution model, someone would need to pay to rent a collection center and pay workers for biol collection, treatment, and distribution. At least at the beginning it would be difficult to find these funds, and it seems Sistema Biobolsa would need to be involved to launch biol sales.

Biol commercialization fits into the broader mission of Sistema Biobolsa. Purchasing biol from biobolsa owners offers existing clients an added benefit, and selling biol to new customers helps the enterprise reach more farmers and extend their social impact. Furthermore, selling biol will help Sistema Biobolsa obtain more biodigester purchasers, as biol offers users a preview of one of the benefits of owning their own biobolsa. Even if Sistema Biobolsa decides to sell biol at or below break-even, it will be an investment in their future and allow for their sustainable solutions to impact more lives.

Distribution Decision Tool

We have created an Excel model with a Google maps overlay that will serve as a short and long term decision making tool for Sistema Biobolsa. For day-to-day functions, technicians will use the "Front-End" tab of the model to determine the radius within which they can drive to pick up and deliver biol. They will simply open the Excel file, update the key assumptions, if necessary, and follow the steps on the "Front-End" tab to open a custom Google map and plot the radius determined by the Excel model.





This model will aid in long term planning for the commercialization of biol by allowing the executive team to change nearly every aspect of the business model. For example, by changing certain variables they can

decide what margin will be paid to producers, what the price of biol will be per hectare compared to chemical fertilizers, and whether the sales will operate at a profit, break-even or be a loss-leader. All of these variables can be modified in the “Key Assumptions” tab, and the results can be seen on the “Front-End” tab, showing the price for retail and producers as well as the distribution radius. These outputs will be critical in determining if the proposed changes will still allow the business model to be viable.

RECOMMENDATIONS

Educate Biobolsa owners to feed biobolsas more often to increase biol production. In order to increase biol production for commercialization, we recommend that Sistema Biobolsa encourage their clients to feed their biodigesters more often. As shown in Figure 3, the potential biol output per farmer per day is over three times their current biol production. Feeding biobolsas daily may not be feasible for every producer, as it involves time and labor, but even increasing the number of days by one or two will make a difference. Additionally, some farmers feed their digesters daily, but only use a portion of their animal waste. If they would like to increase their biol output, they should consider collecting more of their waste. Several farmers expressed concerns that feeding their system every day could cause problems such rupturing the biobolsa. Educating farmers about the pressure release mechanisms will dissipate this fear and may help increase digester feed frequency.

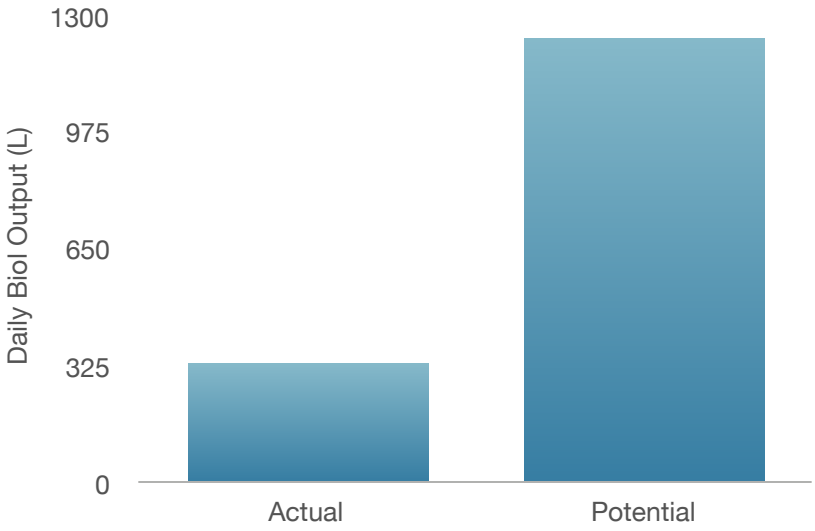


Figure 3. Biobolsa owner average daily biol output: actual vs. potential. Actual biol output is the average of reported biol production according to surveys with producers (n=45). Potential biol output was calculated as if every farmer fed their biobolsa daily and used all of their manure (based on the number of animals they own) (n=51).

Cover biol with a 10-20cm layer of corn husks, plastic pieces, or clay pebbles to prevent ammonia volatilization. Educating Biobolsa owners on proper biol storage techniques is essential. In visits with 56 biobolsa owners, the majority leave their biol uncovered after it leaves the digester. While a few place planks of wood to cover or partially cover their biol, most leave the cistern open to the air and sunlight, exposing biol to ammonia volatilization. This practice is one of the main reasons the reported nitrogen content of biol is lower than expected. We recommend Sistema Biobolsa educate technicians and biobolsa owners about simple covering techniques to prevent nitrogen loss. Regarding covering biol, many Sistema Biobolsa technicians and clients are concerned about covered biol releasing methane, creating a balloon, and causing a small explosion. Accordingly, airtight membranes are not required, but rather a 10-20cm layer of materials such as straw, cornhusks, clay, or plastic pieces.

Improve nutrient retention by immediately incorporating biol into the soil. If biol it is not immediately incorporated into the soil, many of its nutrients will be lost. Sistema Biobolsa should educate their clients on best application techniques. More biol will be absorbed if it is poured on the soil at the base of the plant than if sprayed using a backpack. Additionally, we recommend that Sistema Biobolsa invest in application equipment and offer a biol application service to clients. Use of an injection pump or trailing shoe will greatly improve biol retention in the soil and prevent nutrient loss.

Conduct more tests to understand the true nutrient content of biol. No one will buy biol if they do not know its value, specifically its percentage of nitrogen, phosphorous, and potassium. Many samples of biol need to be taken to obtain a more representative sample of biol nitrogen content. Understanding the true value of biol will help identify the appropriate volume of biol to apply per hectare per crop. Additionally, we recommend comparing biol samples from biobolsa owners with different practices. These comparisons will help validate some of the best practices we highlight in this report.

APPENDICES

Appendix A: Background: Collective Farmer Profile

BIOBOLSA OWNERS

All biobolsa owners surveyed grow maize, primarily for their own self-consumption and to feed their animals. Additionally, many grow other crops such as alfalfa, beans, and barley. Seventy-seven percent of those surveyed have cows, and 39% have pigs. Several have sheep and chickens as well. Most feed their animals some combination of grass, corn, alfalfa, oats, and animal feed.

Farmers use their biobolsas primarily for the biogas. For most, biol was an afterthought. Currently there is a drastic underproduction of biol because many farmers only feed their biobolsa two times per week, as shown in Figure 4. For most, feeding their digester twice a week is sufficient for their gas needs, and many expressed concerns that feeding their system everyday could cause problems such rupturing the biobolsa balloon.

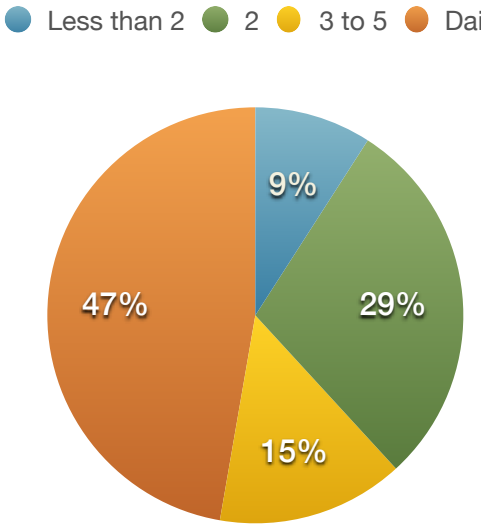


Figure 4. Biobolsa owners, how many times do you feed your biodigester a week? (n=55)

Regarding fertilizer use, most biobolsa owners reported using less chemical fertilizer now that they also use biol. Although several owners interviewed have stopped using chemical fertilizer altogether, the majority are using a mixture of chemical fertilizers and biol, as shown in Figure 5.

POTENTIAL BUYERS

When interviewing potential buyers of biol, we targeted maize and flower growers. We chose maize because it is a highly produced crop in Mexico, and flowers because they offer a shorter growing season, allowing

biol users to see their results faster. Additionally, flower producers cultivate less land compared to maize growers. Of the potential buyers surveyed, maize producers cultivate an average of 2.19 hectares while rose producers cultivate an average of 0.40 hectares. Compared to the difficulty of applying large amounts of liquid across a maize field, as well as the challenge of entering fields when maize grows tall, flowers offer a smaller and more easily accessible area to fertilize.

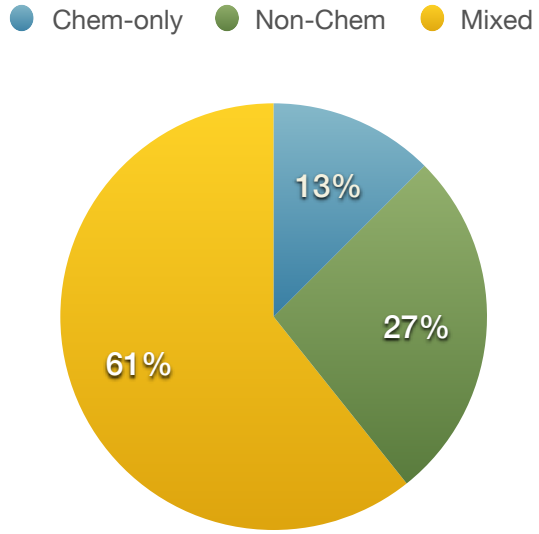


Figure 5. Fertilizer use among biobolsa owners. Chem-Only includes use of any type of chemical fertilizer. Mixed includes users who use both chemical fertilizer and biol. Non-Chem includes those who use biol or no fertilizer at all. (n=56)

Despite their belief that organic is better, these producers continue to use chemical fertilizers for a few reasons. First, many reported that chemicals work faster than organics, and they do not have the luxury of time. Second, chemical fertilizers are what people know, and across the board they expressed a tendency to stick with what works and not take risks. As shown in Figure 7, farmers are spending large amounts of money on chemical fertilizers, and biol presents an opportunity to greatly reduce these costs. Furthermore, several producers expressed a belief that chemical and organic fertilizers work best together. Rather than asking producers to give up chemicals and switch to 100% organic, complementing chemical fertilizers with biol may be a great, and from a buyer's perspective less risky, option.

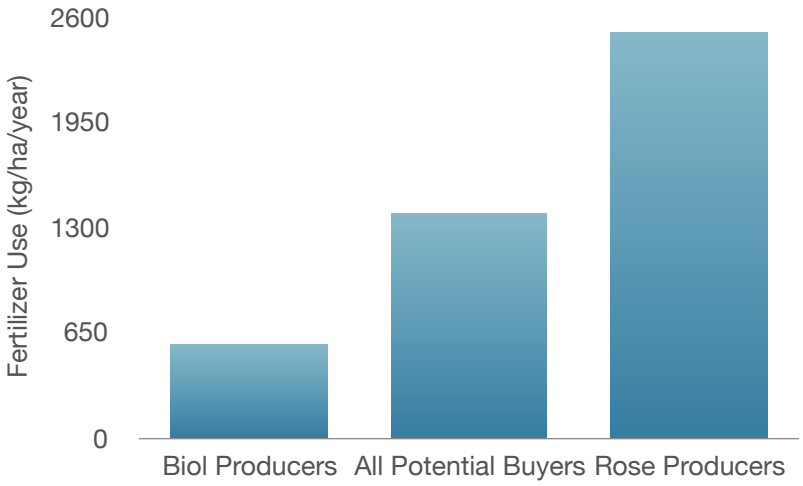


Figure 6. Average yearly fertilizer use among biol producers (n=38), all potential buyers (n=21), and rose producer potential buyers (n=9).

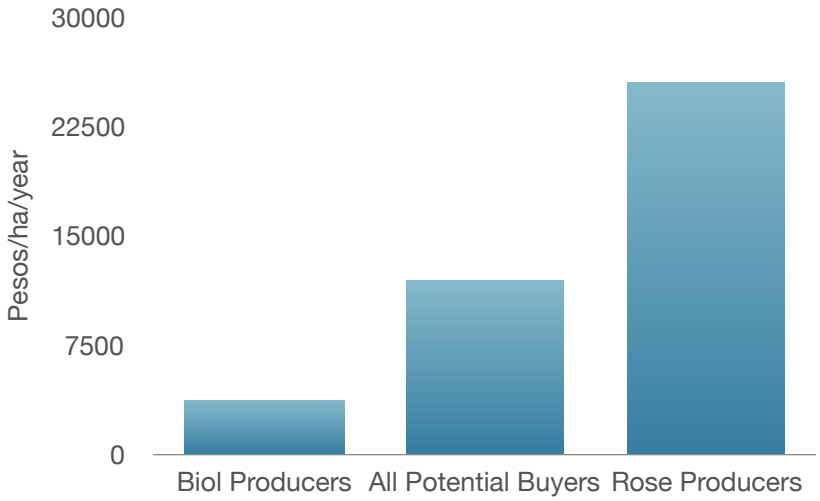


Figure 7. Average yearly fertilizer expenses among biol producers (n=38), all potential buyers (n=21), and rose producer potential buyers (n=9).

Appendix B: References

Al Seadi, T. (2001). Good Practice in Quality Management of AD Residues. International Energy Agency, IEA Bioenergy Task 24. http://213.229.136.11/bases/ainia_probiogas.nsf/0/70996A6A88900B70C125753F005B70AD/$FILE/IEA%20BUENAS%20PR%C3%81CTICAS%20DA.pdf

Al Seadi, T & Lukehurst, C. (2012). Quality management of digestate from biogas plants used as fertilizer. International Energy Agency, IEA Bioenergy Task 37. http://www.iea-biogas.net/files/daten-redaktion/download/publi-task37/digestate_quality_web_new.pdf

Börjesson P & Berglund M (2007). Environmental system analysis of biogas systems. Part II: The environmental impact of replacing various reference systems. *Biomass Bioenergy, 31*, 326–344. doi: 10.1016/j.biombioe.2007.01.004

Cavanagh, A., Gasser, M.O., & Labrecque, M. (2011). Pig slurry as fertilizer on willow plantation. *Biomass and Bioenergy, 2011(35),* 4165 - 4173.

Chiumenti, A., da Borso, F., Teri, F., Chiumenti, R., & Piaia, B. (2013). Full-Scale Membrane Filtration System for the Treatment of Digestate from a Co-Digestion Plant. *Applied Engineering in Agriculture, 29(6),* 985-990. Doi: 10.13031/aea.29.10117.

Hightower, M. & Brown, G. (2004). Evaporation Suppression Research and Applications for Water Management. Sandra National Laboratories. http://www.unm.edu/~cstp/Reports/H2O_Session_2/2-1-Hightower.pdf

Holm-Nielsen, J.B., Al Seadi, T., & Oleskowicz-Popiel, P. (2009). The future of anaerobic digestion and biogas utilization. *Biosource Technology, 100(22),* 5478-5484. doi: 10.1016/j.biortech.2008.12.046

Lukehurst, Clare T., Peter Frost, & Al Seadi, T. (2010). Utilisation of digestate from biogas plants as biofertiliser. International Energy Agency, IEA Bioenergy Task 37. http://www.iea-biogas.net/files/daten-redaktion/download/publi-task37/Digestate_Brochure_Revised_12-2010.pdf

Nkoa, R. (2013). Agricultural benefits and environmental risks of soil fertilization with anaerobic digestates: a review. *Agronomy for Sustainable Devevelopment, 2014(34)*, 473–492. doi: 10.1007/s13593-013-0196-z

Pell Frischmann Consultants Ltd. (2012). Enhancement and treatment of digestates from anaerobic digestion. *Wrap UK.* http://www.wrap.org.uk/sites/files/wrap/Digestates%20from%20Anaerobic%20Digestion%20A%20review%20of%20enhancement%20techniques%20and%20novel%20digestate%20products_0.pdf

Sicilliano, A. & De Rosa, S. (2013). Recovery of ammonia in digestates of calf manure through a struvite precipitation process using unconventional reagents. *Environmental Technology, 35(7)*, 841-850. doi: 10.1080/09593330.2013.853088.

Warnars, L. & Oppenoorth, H. (2014). Bioslurry: A Supreme Fertiliser: A study on bioslurry results and uses. *Hivos People Unlimited.*

Appendix C: Digestate Treatment

Table 1. Digestate Enhancement Techniques

Physical	Thermal
Thickening (Belt)	Drying (Rotary Drying)
Thickening (Centrifuge)	Drying (Belt drier)
Dewatering (Belt press)	Drying (J-Vap)
Dewatering (Centrifuge)	Drying (Solar)
Dewatering (Hydrocell)	Evaporation (scraped surface heat exchangers)
Dewatering (Bucher press)	Conversion (Incineration)
Dewatering (Electrokinetics)	Conversion (Gasification)
Purification (Ultrafiltration and Reverse Osmosis)	Conversion (Wet air oxidation)
	Conversion (Pyrolysis)

Biological	Chemical
Composting	Struvite precipitation
Reed Beds	Ammonia recovery (Stripping + Scrubbing)
Biological Oxidation	Ammonia recovery (Membrane Contactor)
Biofuel Production (Algae)	Ammonia recovery (Ion Exchange)
Biofuel Production (liquor as process water)	Acidification
Biofuel Production (hydrolysis of fibre to Bioethanol)	Alkaline Stabilisation
Microbial Fuel Cell	

Source: Pell Frischmann Consultants Ltd. (2012). Enhancement and treatment of digestates from anaerobic digestion. *Wrap UK.* http://www.wrap.org.uk/sites/files/wrap/Digestates%20from%20Anaerobic%20Digestion%20A%20review%20of%20enhancement%20techniques%20and%20novel%20digestate%20products_0.pdf

Appendix D: Methods

We spent seven weeks working with Sistema Biobolsa out of their field office in Puebla, Mexico. First we visited Sistema Biobolsa clients throughout the states of Puebla and Tlaxcala, ultimately surveying 56 biobolsa owners, who we termed biol producers. Interviews consisted of about 30 questions regarding the client's crop production, farming techniques, chemical fertilizer use, animal ownership, biodigester feeding practices, and biol use. The goals of these surveys included identifying biol practices among biobolsa owners and gauging their interest in selling biol and their ability to do so.

Next we surveyed 29 non-biobolsa owners, categorizing them as potential biol buyers. These potential buyers included any farmer in the area growing crops, who therefore most likely uses some kind of fertilizer or has fertilizer needs. We identified these potential buyers mainly through either biobolsa owners or Sistema Biobolsa technicians who referred us to friends and family. Surveys with these potential buyers asked about their crop production, farming techniques, chemical fertilizer use, preferences for chemical vs. organic, and interest in purchasing biol. The main goal was to gauge their interest in purchasing biol and their needs for the product.

Lastly, through our surveys with biol producers and potential buyers, we identified local agrochemical houses, *casas de agroquímicas*, as a potential partner for biol distribution. We interviewed workers at nine local agrochemical shops, asking about the chemical, organic, and liquid products they sell and their interest in taking on a new natural liquid fertilizer such as biol. The goal was to gauge the feasibility of selling biol through agrochemical houses.

Appendix E: Research Limitations

Our sample size of 56 biobolsa owners is rather small, considering Sistema Biobolsa has over 2000 clients. However we visited owners of various sized digesters and began receiving similar responses across the board. Surveying only 29 potential buyers was also a small sample size, but we intentionally sought out both maize and rose producers to gauge interest from different types of producers. Although our sample is small, our findings regarding both biobolsa owners and potential buyers mostly align with the anecdotal knowledge of Sistema Biobolsa technicians who know their consumer base much better than we do, and our findings help put numbers behind their existing beliefs. Our sample of only nine agrochemical houses is very small, but it was only intended as a first look into these shops as potential distributors. These nine interviews gave us a preliminary understanding of the opportunity regarding agrochemical houses, but further work needs to be done if this avenue is going to be pursued in the future.

Our position as foreigners presented some limitations. As non-native Spanish speakers we occasionally faced communication issues because of our limited vocabulary and unfamiliarity with all aspects of rural Mexican culture. For the most part communication was successful, but

little misunderstandings may have affected some responses. Sistema Biobolsa technicians were almost always present during interviews to help clarify responses, if needed.

We recognize that many of our survey questions asked respondents to speculate about their future choices and actions. It can be difficult for anyone to predict what they will do in the future, especially smallholder farmers who cannot control many aspects of their livelihood, such as weather patterns and fertilizer prices. While their responses help give us an idea of their interest in buying or selling biol, we must understand their responses now may be very different from their actual decisions in the future.

Appendix F: Interview Guides

BIOL PRODUCER INTERVIEW GUIDE: ENGLISH

Name
Local
Digestor capacity
Reference number

- What type of crops do you have?
- How many hectares of land do you cultivate?
- How much do you produce?
- Is your harvest for self-consumption or do you sell it?
    - If you sell it, where?
- Do you use chemical fertilizers?
    - What kind
    - How much?
    - How much do you pay for fertilizer?
    - How do you apply the fertilizer?
- What type of animals do you have and how many?
- What do your animals eat?
- How much animal waste do you collect each day?
- How often do you feed your biobolsa?
- What is your waste/water ratio?
- How many liters of biol do you produce daily?
- What are you currently doing with your biol?
    - How do you apply biol to your fields?
    - When do you apply biol?
- Do you have an excess of biol?
    - If so, how much?
- How many hours of gas does your biodigester produce?
- Do you have an excess of gas?
- Are you interested in selling biol?
- Have you paid completely for your digester or are you still paying off a loan?

- If you were to sell biol, what price would you like to receive?
- How often do you leave your community?
- If we created a collection center would you sell your biol there?
    - Do you have access to a vehicle?
    - What containers do you have to put the biol in?
    - Would you need someone to come collect it?
- Do you know neighbors or family members who would be interested in buying biol?

BIOL PRODUCER INTERVIEW GUIDE: SPANISH

Nombre
Localidad

- Qué tipo de cultivo tiene?
- Cuántas hectáreas de tierra cultiva?
- Cuanto produce?
- La cosecha es de autoconsumo o lo vende?
    - A donde va para venderlo?
- Utiliza fertilizantes químicos?
    - Qué tipo?
    - Qué cantidad usa
    - Cuanto paga por el químico?
    - Como aplica el químico?
- Qué tipo de ganado tiene y qué cantidad?
- Qué comen sus animales?
- Cuanto estiércol recoge por día?
- Cada cuando alimenta su biobolsa?
- Qué es la cantidad de estiércol con agua?
- Cuantos litros del biol produce cada día?
- Qué haces con el biol? Se lo da a vecinos o familiares?
    - Cómo aplica el biol?
    - Cuando aplica el biol?
- Tiene una sobra del biol? Cuanto?
- Cuantas horas de biogás produce su biobolsa cada día?
- Tiene una sobra de biogás?
- Tiene interés en vender el biol?
- Pagó completamente por el biobolsa o todavía esta repagando el préstamo?
- Si usted vendería el biol, que precio le gustaría recibir?
- Con que frecuencia sale de la comunidad?
- Si creamos un centro de colección del biol, usted vendería su biol al centro?
    - Tiene acceso a una camioneta?
    - Tiene contenedores para colectar el biol?
    - Necesitaría aliguen para venir y colectar el biol?
- Conoce vecinos o otras personas que tienen interés o podrían tener interés en comprar el biol?

POTENTIAL BUYER INTERVIEW GUIDE: ENGLISH

Name
Local

- What type of crop do you have?
- How many hectares do you cultivate?
- How much do you produce?
- The harvest is for auto-consumption or do you sell it?
    - Where do you sell it?
- Do you use chemical fertilizer?
    - What type?
    - How much?
    - How much do you pay?
    - Where do you buy it?
    - How do you apply it?
- In addition to chemical fertilizers, do you buy other agricultural products?
- How often do you leave your community to go to a city?
- Do you have irrigation?
- Which do you think is better, chemical or organic fertilizer?
- Have you heard of biol or used biol?
- Are you interested in buying biol?
    - If we create a collection center, would you go there to purchase biol?
    - Do you have access to a truck?
    - Would you pay more, less, or the same for biol as for chemical fertilizer?

POTENTIAL BUYERS INTERVIEW GUIDE: SPANISH

Nombre
Localidad

- Qué tipo de cultivo tiene?
- Cuántas hectáreas de tierra cultiva?
- Cuanto produce?
- La cosecha es de autoconsumo o lo vende?
    - A donde va para venderlo?
- Utiliza fertilizantes químicos?
    - Qué tipo?
    - Qué cantidad usa
    - Cuanto paga por el químico?
    - Donde lo compra el químico?
    - Cómo aplica el químico?
- Además de los fertilizantes químicos, compra otros productos agrícolas con frecuencia?
- Con que frecuencia sale de la comunidad para ir a alguna cuidad?
- Tiene riego?
- Cual cree que es mejor, fertilizantes orgánicos o químicos?
- Usted ha escuchado del biol o ha usado el biol?
- Tiene interés en comprar el biol?
    - Si creamos un centro de acopio del biol, usted iría al centro para comprar el biol?
    - Tiene acceso a una camioneta para transportar el biol?

- Pagaría mas, menos, o lo mismo por el biol que paga por el fertilizante químico?

AGROCHEMICAL HOUSES INTERVIEW GUIDE: ENGLISH

- Prices of chemical fertilizers: retail (with and without subsidy) and wholesale
  - Urea, 18-46, Triple, Phosphorous, Potassium
- What percentage of your customers uses the government subsidy?
- Where do you buy fertilizer? Is there a distributor? Do you have a contract with a distributor or fertilizer producer?
- Do you sell organic fertilizers?
  - What type?
  - If so, how do they sell?
- Would you be interested in a selling a liquid organic fertilizer?

AGROCHEMICAL HOUSES INTERVIEW GUIDE: SPANISH

- Que es el precio del químico sin y con el subsidio/apoyo? Que es el precio al por mayor?
  - urea, 18-46, triple, fosforo, potasio
- Que porcentaje de sus clientes compran con el subsidio/apoyo?
- Donde compra fertilizante? Tiene un distribuidor? Tiene un contrato con un distribuidor o un productor?
- Vende fertilizantes orgánicos?
  - Que tipo?
  - Son populares? Vende mucho?
- Tiene interés en vender un fertilizante orgánico liquido?

Appendix G: Data Collection Sheet

Sistema Biobolsa Client Survey

I. Demographic info

Name	
Area	
Reference #	
Phone #	
Biodigester Cap	

II. Fertilizer

Do you use Chem Fertilizer?	( ) Yes		( ) No
What Kinds?	( ) Urea	( ) 18-4	( ) Other:
How much per Hectare?	KG	Bags	Tons
How much do you pay?			
How do you apply	( ) Manual	( ) Yunta	( ) Other:

III. Livestock

Livestock type:	( ) Adult Cow	( ) Young Cows	( ) Adult Pig	( ) Young Pig	( ) Other:
Number					
Feed type					

IV. Biobolsa

How often do you feed Digestor?	( ) Every day	( ) Third Day	( ) Other
Daily animal waste?	Buckets		Wheelbarrow
Waste/water Ratio?	( ) 1/3	( ) Other:	
Daily Biol Production			
Current Biol Use	( ) Own Fields	( ) Give away	( ) Other:
How do you apply Biol?			
When do you apply biol			
Do you have excess biol	( ) Yes	( ) No	
How much?			
Hrs of Gas produced			
Excess Gas?	( ) Yes:		( ) No

V. Market Interest

Interested in selling Biol	( ) Yes	( ) No	
Loan Status	( ) Fully-Paid	( ) Still Repaying	
Potential Price			
Places frequently visited			
Would you sell at collection center?	( ) Yes	( ) No	
Access to Truck?	( ) Yes	( ) No	
Containers for Biol?	( ) Yes	( ) No	
Neighbor interest?	( ) Yes		( ) No
Potential complications?			

VI. Notes