Evaluating Biodigestor Technology's Impact on Rural Women and Sustainability in La Florita, Limón, Costa Rica

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I. Personal Introduction

Ironically, even though I grew up in Waukee, Iowa with a cornfield across from my high school, agriculture was a foreign concept to me. No one in my family had farmed in generations, and I gave little thought to where my food came from and even less to the agriculture system in developing countries until I participated in the World Food Prize Youth Institute in October 2009. Researching climate change's impact on Malawi and attending the symposium, I experienced a wider range of emotions than I could have ever imagined: shock, disbelief, anger, heartache, confusion, compassion, hope. I left the weekend transformed from apathetic to impassioned, convicted especially by the simplified representation of rural poverty at the event's hunger banquet. Little did I know that the rice and beans that was served that night would foretell the same meal I would share with rural farmers in Guácimo, Costa Rica.

At the time, I chose not apply for the internship but still retained an interest in food security, especially in relation to environmental and international health. After I entered the University of Iowa to study microbiology and global health, I gained the confidence, skills, and perspective needed to transition from an idle interest in food security to a proactive advocate for change and applied for the internship. I was later accepted and placed at EARTH University in Guácimo, Costa Rica—a new internship site. As my departure approached, I found out that I would be working in community development, conducting social science research in the field, working entirely in Spanish, and spending long days on the farm for the first time in my life.

II. Research Background

1.1 EARTH University

Developed in 1986 with support from the Costa Rican government, USAID, and the Kellogg Foundation, EARTH University (*Escuela de Agricultura de la Región Tropical Húmeda)* was established as a private, non-profit international institution in response to Central American's economic and political turmoil in the 1980s. Unsustainable agricultural techniques fueled much of the distress: natural resource depletion in the tropics propagated social inequalities and reduced opportunities for the young, especially those who lived in rural areas. The University emerged to empower these young people and grew to become a leading research center for tropical agriculture and sustainable development. Students from twenty-nine different countries now comprise the student body and after four years of experiential learning and holistic education, graduate to become some of the most innovative and passionate agricultural leaders in the world. The campus, an 8,154-acre parcel, includes an active commercial banana plantation, an organic farm, a periurban garden, biological reserve forest, a fish farm, and a dairy farm among other agricultural plots to demonstrate to students and tourists that sustainability—both economically and environmentally—is possible.

1.2 Community Development Program (PDC)

Situated in the eastern lowlands—the traditionally poorest part of the country—EARTH University students and faculty transfer the research and skills learned on campus to the people who need it the most: the rural farmers. To provide this bridge, the W. K. Kellogg foundation donated the necessary support to make way for the creation of the Permanent Education Program (PEP), which includes entrepreneurial training, visitor facilities, and the PDC. Facilitating the transfer from classroom to community, the PDC helps thousands of people in local rural areas every year implement best practices, sustainable development, and proper management of resources on their farms. Students and faculty work directly with small producers and hold weekly open classrooms to facilitate discussion.

For my Borlaug~Ruan International Internship, I was placed under the supervision of Fabián Campos, who directs many of the PDC's programs, and I spent much of my time in local rural communities, observing the PDC's programs and working alongside students and small producers in their farms. Initially, I was not assigned a particular research project, and I served more of a support role, providing an extra set of hands to carry out the vision of food security and environmentalism in the communities. However, after I had the opportunity to examine and fix biodigestors with the PDC's head engineer, Luis Carazo, I became interested in further investigating the effect that biodigestors had on rural families—especially rural women—and the sustainability of the PDC's biodigestor program. From there, I developed a research proposal, presented it to the team, and once approved, began developing the project first-hand.

1.3 Justification

In many studies, women have been demonstrated to have the most influence on nutrition, health, and education within Costa Rican households (Ashby et al. 1). However, the role of the woman has changed in recent years to meet the needs of the family. One of the main changes has been for women to assume various workday responsibilities in same day; thus, it is probable they will work in the farm and take care of the children at the same time. Consequently, these responsibilities may leave fewer time and resources and less energy available for women to invest in themselves in areas such as self-education and microenterprises.

Novel technology, such as biodigestors, have emerged as a way that could improve women's quality of life and allow them to have more time for themselves, and research at EARTH and other leading institutions has shown that biodigestors have the capacity to improve health, cut energy costs, and decrease time spent on cooking-related activities. The success of biodigestor installation hinge on the actualization of these positive outcomes for participants, particularly women, who are typically the primary cooks and thus the primary beneficiaries of the new technology. However, these outcomes have not been confirmed in many communities, including La Florita, a rural settlement in which the PDC is currently installing biodigestors.

As a result, my work centers on conducting a performance evaluation of the project in the community: it determines whether benefits in regards to time, health, and financial security are achieved for rural women and whether the project is sustainable at the community-level after successful biodigestor installation. Sustainability in this sense

is correlated to the self-sufficiency—or conversely, dependence on the university—for maintenance and upkeep of the biodigestor.

The importance of the present research rests, chiefly, on the fact that the findings may call for a revision of some of the PDC's activities in the biodigestor project. In this sense, the investigation opens the road for subsequent specific evaluations and improvement of the effectiveness of the implemented strategies.

1.4 Objectives

1.3.1 Determine the existence and the consequences of reduced cooking time, increased financial security, and improved health on the lives of women after successful biodigestor installation.

1.3.2. Determine the level of sustainability of the biodigestor project after installation in the community of La Florita.

1.5 Research Questions

1.4.1 Do the women spend less time on cooking-related activities during the day, and if so, how do they spend the extra time?

1.4.2 Do the families have greater financial security as a result of the biodigestor, and if so, how do they invest the savings?

1.4.3 Do the women have better health as a result of the biodigestor, and if so how does improved health affect their lives?

1.4.4 Is the biodigestor project sustainable in the community after installation?

1.5 Methodology and Limitations

First, a literature review was conducted to determine the context of gender issues, subsistence agriculture, and daily life of the rural poor in Costa Rica. Extensive background studies on biodigestor installation, maintenance, and home-level benefits were also conducted both through literature review and experiential learning on site in La Florita.

Based on the conceptual and background research, a survey was then generated to gather both quantitative and qualitative data; this survey can be viewed in the appendix. Questions were pre-tested with EARTH faculty and students to gauge effectiveness of wording and estimate time of interviews. When I arrived in the community, eleven out of fifteen women in La Florita who had biodigestors in their households were interviewed: nine were interviewed on July 4, 2012, and the two were interviewed on July 10, 2012. Four of the women I intended to interview were not able to be located on either of the days. Each interview lasted between 15-30 minutes and was conducted in Spanish without the aid of a translator or guide.

After all the interviews were conducted, I entered all the quantitative data into an Excel spreadsheet and transcribed selected qualitative portions of the interviews. I then complied and analyzed my results through Excel, drew conclusions, and conducted further bibliographical research to determine ways in which the PDC could improve their biodigestor program so that more potential benefits could be accomplished in La Florita.

Bias was present in the interviews in several ways. Despite my requests, I was unaided by a translator or native speaker during the interviews and chose to record the conversations, which may have affected some of the responses. Another factor that

threatened the integrity of the responses was the presence of family members, particularly husbands, during two of the interviews despite my attempt to interview the women alone. Another issue that affected research outcomes was the invalidity of question 4.1 (see in appendix), which centered on the household cost of electricity before biodigestor installation. After four interviews, I realized that electricity was only introduced into the community after these biodigestors had been installed, and therefore, the cost savings could not be measured by differences in electricity costs. However, I came to the understanding that cylinders of propane gas were used for cooking as well and were often used before biodigestor installation. Consequently, I made the decision to change the questions for the remaining interviews, which resulted in less data generated and this may have affected my results.

For future performance reviews and research, I believe that questions should be pre-tested in another rural community, especially if the interviewer is a non-native Spanish speaker and will not have the aid of a translator. Back-translation may also be necessary to ensure accuracy. I would also suggest that interview subjects be made aware of the interview date(s) in advance, as every woman has a unique story and circumstance that may contribute to data generated, conclusions drawn, and suggestions proposed. Focus group discussions could also be held to gain increased understanding of issues the women believe of high importance. Finally, I would also suggest that data analysis software such as SPSS be used to aid in data analysis.

III. Conceptual Background

2.1 The Rural Woman

According to the United Nation's Economic Commission for Latin American and the Caribbean (CEPAL), 69% of all the poor in Costa Rica live in rural areas (Gutiérrez, 2012). In these cases, normally women are "the principal agents of food security and household well-being" and a majority of the workforce in subsistence agriculture (Ashby et al. 1). Therefore, women are very important to the future of the farm, community, and family in Costa Rica. However, the increasing food prices in recent years and other cultural and social factors have limited women's access to food. Despite the fact that women are a large proportion of the agricultural workforce, they have suffered from limited access to off-farm employment. In consequence, while many men look for work off the farm or cultivate crops to sell at the market, most women solely work on family farms and cultivate crops and breed animals only for household consumption. Often, these women are never paid, and if they do receive wages, they earn only 53% of the men's salaries in Costa Rica ("Gender Dimensions of Rural and Agricultural Employment"). This economic and social inequity has given rise to the phenomenon known as "the feminization of the poor."

In addition to their work on family farms, women are the only ones in the household to attend to domestic duties that include taking care of the children, housework, and cooking. However, despite the fact that they work on average more than sixteen hours a day, Costa Rican society perpetuates the view that women are only helpers to the household's male figure and that their work is not a true economic activity; this point of view often affects development (Chiriboga et al. 91, 95, 104 [translated by

author]). In effect, social norms dictate that the husband controls the household's money and makes all final decisions.

This inequity is present in schools and development programs as well. For example, in fifty-one technical-professional secondary schools in Costa Rica, nineteen did not have any female students (Chiriboga et al. 94 [translated by author]). Similarly, women do not benefit from development programs from IDA[1] and MAG[2] as much as men: only 11.8% of total direct beneficiaries were women in the first twenty-five years of IDA (Chiriboga et al. 98 [translated by author]). Also, despite the fact that no Costa Rican law impedes women's access to land, women still have limited access, largely due to the patriarchal culture. However, this inequity is not limited to societal and cultural views; unfortunately, many women themselves believe that men should be the ones to actualize technical and commercial agricultural endeavors (Chiriboga et al. 94 [translated by author]).

2.2. PDC Biodigestor Program

2.2.1 Biodigestor Form and Function

The small-scale, Taiwanese biodigestor installation process is simple and easily implemented on Costa Rican rural farms. An open plot of land is needed adjacent to a livestock corral for access to the animals' waste, and a brick and cement canal is constructed to connect the animal pens and the biodigestor. The size of the biodigestor is determined by the number and type of animals available and the amount of waste they tend to produce, and a pit is then dug to accommodate the determined size. Next, the polyethylene bag is cut, and "mouths"—an entrance for animal and food waste and an exit for the semi-solid product of the biodigestor—are created. Then a gas exit is assembled from PVC and plastic tubes: two tubes are connected to the biodigestor (one for a gas exit; one, a gas entrance) and are connected to the bags. An additional gas exit, consisting of a short tube leading to a half-full water tank, is also created through the top of the biodigestor: it serves the purpose of relieving pressure in the case that too much gas builds up and is not released through sufficient cooking. Once the biodigestor has been assembled and placed in the pit, it is inflated with air, and a series of tubes is made to connect the biodigestor and the stove. To protect the new technology, fences to keep out children and animals and roofs to block out solar radiation should be made as well. Depending on the quality and quantity of the wastes, the completed biodigestor could be ready to power the stove in less than a week and can last up to 15 years without bag replacement with proper maintenance.

To keep costs down and promote sustainability, the PDC uses recycled material when whenever possible. For example, the biodigestor's "mouths" are often made from used plastic buckets or tubes, often found on the side o the road, and outfitted for the biodigestor. An annotated example of a PDC-made biodigestor can be viewed below in Figure 1.

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[1] The Institute of Agricultural Development (IDA) was created by the Costa Rican government in 1961 to redistribute land in order to maximize agricultural production and to create small producers. Its purpose was to establish social equity and prevent social unrest.

[2] The Ministry of Agriculture and Livestock (MAG) is responsible for promotion of economic competition and the development of livestock activities in rural areas. These ideals work in harmony with the protection of the environment and natural resources.

Figure 1: Taiwanese Biodigestor in La Florita

Biodigestors function by utilizing the anaerobic fermentation of animal and food wastes in a closed system to liberate methane from biomass as an energy source and consequently eliminate animal husbandry methane emissions, which have a 21 times greater effect on the greenhouse effect than carbon dioxide (Lansing et al. 2). This biogas can be piped through a tubing system to the house and used as an energy source for cooking, lighting, and water supply. In addition, a soluble, nitrogen-rich liquid is produced and can be used as an organic fertilizer. As more biomass is inputted, a greater output of organic fertilizer and biogas can be expected.

The digestion process begins with the bacterial hydrolysis of the inputted macromolecules—including carbohydrates, lipids, and proteins—in to their respective monomers (simple sugars, fatty acids/glycerol, and amino acids). At this point, another group of bacterium, called acidogenic bacteria, further simplify these substrates into molecules such as organic acids, hydrogen gas, ammonia, and carbon dioxide. The organic acids are broken down again by acetongenic bacteria to form acetic acid; in the process, more hydrogen, ammonia, and carbon dioxide are produced as well (Marshall and Energy). An example of the chemical basis for this process is expressed by equation set 1 below (Sawyer et al. 241).

Equation Set 1: Acetongenic Fermentation from Glucose

$$C_6H_{12}O_6 + 2H_2O \leftrightarrow 2CH_3COOH + 2CO_2 + 4H_2$$

Finally, methanogenic bacteria convert all of these products into methane and carbon dioxide, which can be directly harvested to provide fuel for cooking (Marshall and

Energy). Methane fermentation from acetate and carbon dioxide can be quantified through equation set 2 below (Sawyer et al. 242).

Equation Set 2: Methanogenic Fermentation

$$2.5\ CH_3COO^- + 2.5\ H^+ \rightarrow 2.5\ CO_2 + 2.5\ CH_4$$
$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2$$

The resulting biogas is composed of between 50-70% methane and 30-40% carbon dioxide (Lansing et al. 2).

In order to form the most ideal environment for the bacteria and maximize system efficiency, the wastes of the pigs or cow should be mixed in a 1:5 proportion with water. For example, to produce between 2-4.5 hours of biogas per day, 20 kg of excrement should be diluted in 100 liters of water. This amount of waste is expected to be generated from 3-5 pigs or one cow (Universidad EARTH 2 [translated by author]).

2.2.2 Household and Environmental Benefits

Before biodigestor installation, many families used wood as the source of energy for their stove. Collection of wood is a tedious process, and wood also produces a relatively cool fire, both resulting in a lengthening of the cooking process. In addition, the use of wood may have consequences for the family health and the environment. In Costa Rica, many kitchens are located within the home because the women do not want to travel between the home and an outdoor kitchen in the tropical climate. Therefore, when the wood burns, the smoke and smell linger in the house, remaining in the clothing and bedding. The smoke can have health consequences for the family and affect quality of life. The environment is also affected: in order to obtain wood, many rural families contribute to deforestation and consequently the reduction of biodiversity in the world's largest ecological "hot spot." In addition, the resulting smoke of burning the wood is a source of air contamination. In contrast to wood burning, the biodigestor provides a source of clean, safe, and hot gas that does not have a bad odor and reduces the time needed for cooking.

If the families do not cook using wood, most often they use electricity, which can prove expensive. With the biodigestor, families can use the saved money to invest in education, health, farm expansion, and microenterprises among other endeavors. In addition, the cost of installing and maintaining the biodigestor is relatively low, and these needs have the potential to create other sectors of the community economy.

Another benefit of the biodigestor is the production of a safe fertilizer. Traditionally, animal wastes were a source of water, soil, and food contamination. However, the fertilizer produced by the biodigestor is safe because the anaerobic environment in which it is produced and the time it spends fermenting prevent the growth of pathogenic bacteria and kill intestinal parasites (Rodriguez and Preston).

2.2.4 Program Structure

The University identifies communities that could benefit from biodigestor technology, and environmentally conscious producers with entrepreneurial spirits are invited to tour the University's biodigestors and learn more about the benefits of biodigestor installation for small-scale farms. Biodigestors are installed at interested producers' homes for little to no cost to the producer; EARTH or outside donors typically supply the average of $200 required for the installation process and materials. At least one family member must be present at installation to receive training on biodigestor use and maintenance. As a community begins installing more biodigestors, a community leader is identified and trained further in biodigestor upkeep and maintenance. However, EARTH still plays an integral role in upkeep: faculty and students are available for repair, maintenance, and improvement for no charge.

2.3 La Florita

La Florita is a settlement of twenty-nine agricultural plots and was developed by the IDA in 2006. The community lacks potable water, and electricity has just been made available to the parcels along the main roads within the last three years. Each farm consists of three hectares, and agriculture, particularly cultivation of tuberous crops, is the main form of income and livelihood. The homes are typically made of plastic or wood walls with dirt floors and generally have two rooms.

The development of the biodigestor project began in November 2009 with the financial support of Green Empowerment and WISIONS International and was implemented by the PDC's Aula Abierta (open classroom) program. The project was designed to minimize water contamination from pig wastes and curb deforestation, as the community was heavily reliant on wood for cooking. (Universidad EARTH 3 [translated by author]).

IV. Data Analysis

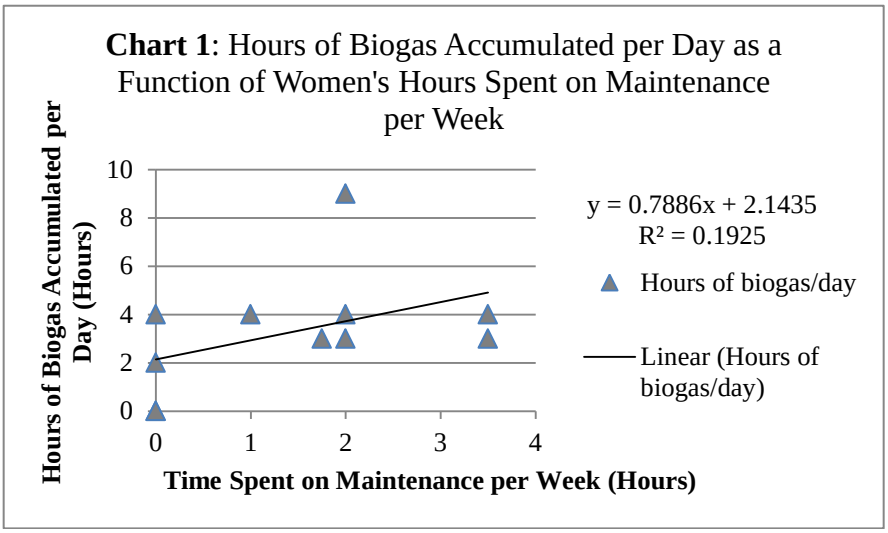
4.1 Daily Life

The average age of the women interviewed was 44 years and nine months, and the average family size was 4. All women had only completed primary education through the sixth grade. The average length of time spent living in La Florita was 5 years and 5 months, and the average amount of time using a biodigestor was 2 years and 9 months. Generally, the biogas was sufficient for an average of 4 hours and 8 minutes of cooking, but the principal cook—the woman of the house in every interview—reported dedicating an average of 6 hours and 23 minutes of cooking every day[3]. In effect, the biodigestor only supplied an average of 64.8% of the families' cooking energy needs.

In the maintenance of the biodigestor—which includes cleaning animal corrals, raking the excrement/water slurry into biodigestor mouth, and weeding the surrounding area among other responsibilities—the women reported spending an average of 59 minutes each week.

[3] The concept of time in Costa Rica and much of Latin America tends to be more fluid that that of Western society, and in particular, it was difficult for many women to estimate the amount of time they spent cooking with precision. Time-related data in this study should consequently be viewed as an estimate rather than an absolution.

A correlation between the time spent on maintenance per week and the hours of biogas accumulated per day can be seen in Chart 1 below.



As seen above, a slight correlation (R^2= .1954) exists between the hours of maintenance per week and hours accumulated per day. This data does not account for hours of maintenance inputted by men and children, however.

The table below shows the primary and secondary sources of energy for cooking among the eleven households. Four women said that they had two secondary sources, and one said she had three secondary sources. In addition, one woman said that her family used biogas approximately half the time and wood the other half; these sources were both considered primary sources in the table.

Table 1: Primary and Secondary Sources of Energy for Cooking

	Biogas*	Electricity	Wood	Propane Gas
Primary Source	9	2	1	0
Secondary Source	0	3	9	2

*Even though eleven women were interviewed, two indicated that their biodigestors were not functioning at the time of the interview. This can be seen in Table 8.

Although 90.9% of women expressed some dependence on wood energy sources, some of the women explained that wood was only used in order to cook beans and soup because the biogas alone did not produce a hot enough flame. One woman said that even though biogas is sufficient for her cooking needs, she still uses wood because she enjoys cooking with it.

Below, Table 2 indicates the principal uses of the biodigestor among the families. Two women had two responses.

Table 2: Uses of Biogas

	Cooking	Lights	Water
Frequency	10	2	1

The majority of respondents (72.7%) indicated that the biogas was only used for cooking.

Table 3 below demonstrates the perceived difference in cooking time between before and after the biodigestor's installation.

Table 3: Perceived Cooking Time Difference by Percentage of Respondents

	Less	More	Same
Frequency	0	2	9

It is important to point out that the biodigestor did not save time in any of the cases, but for 81.8% of the women, it did not increase the time required for cooking either. This indicates that their daily activities and prioritization were not affected significantly. For 18.2% of the cases, the additional time required may have affected daily activities to some extent. The two who indicated more time was spent on cooking now both credited the increased time spent to the observation that the flame produced with biogas was not as hot as that produced by wood.

4.2 Economy

Below, Table 4 demonstrates the primary and secondary sources of income for the houses. Six women (54.5%) said that agriculture was the only source of income.

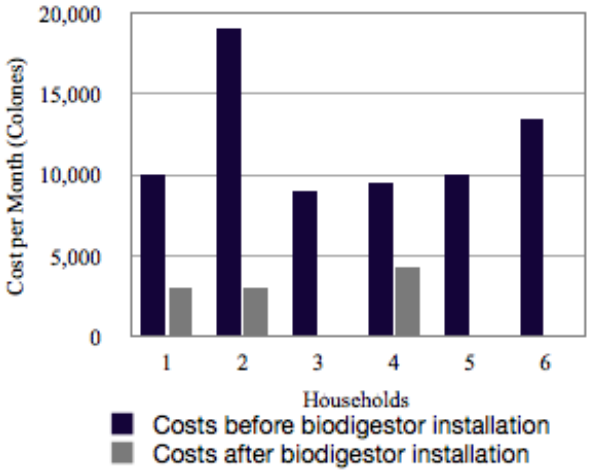
Table 4: Primary and Secondary Sources of Income

	Agriculture	Husband's Off-Farm Work	Pension
Primary Source	9	2	0
Secondary Source	2	1	2

In this table, it is important to note that the families who indicated that agriculture was their secondary source of income have just as much responsibility to the land as the families who noted agriculture was their primary or only source of income. For these two families, however, their economic diversification is greater, so they are less vulnerable to market conditions. On the other hand, families who express agriculture as their primary source of income tend to have a higher return on their assets.

As noted in the field, many biodigestors were installed before electricity was available in the community. However, some houses used propane gas tanks for their cooking. The chart below shows the amount of propane gas purchased each month before and after the biodigestor's installation. Only six women were able to answer this question, and the chart does not take into account the current costs of electricity for cooking.

Chart 2: Expense of Propane Gas Before and After Biodigestor Installation



On average, the families saved 10,042 colones, which equates to approximately $20.10, because the propane gas cylinders lasted longer or the families eliminated the use of propane gas entirely, as shown in households 3, 5, and 6.

It is evident from the graph that the biodigestor has had a positive impact on family finances, so much so that in 50.0% of the cases, propane gas has disappeared as an energy source for cooking. In the other 50.0%, although they still purchase some propane gas, its cost in relatively low respectively in comparison to when there was no biodigestor on the plot.

Among these six families, three indicated that they had "extra" money after the cost of electricity for cooking. Below, Table 5 shows how the women invested the money. Two women had two areas of investment; one woman, three.

Table 5: Use of "Extra" Money

	Clothing and Shoes	Food	Television
Frequency	1	3	1

When the women responded with "food," they said that they bought more specialty foods like cheeses and meats and also more healthy foods like vegetables. This table indicates the expenditure prioritization within the three homes. Food security is the upmost priority in all three homes and is followed by clothing and household items, including a television in one case.

4.3 Health

The following tables show the opinions of the women about if and how having biodigestors has affected their health and the health of their families.

Table 6: Opinions about if the Biodigestor is Related to the Increased Health of the Family

	Yes	No
Frequency	8	3

Thus, 26.3% of the cases indicated that the biodigestor has not impacted the health of the family while 72.7% of the cases indicated that it has had a positive impact on health of those using the biodigestor. None of the cases indicated that the biodigestor negatively affects the health of the family.

Table 7 shows the perceived effects of the biodigestor on the health of the eight women who believed that the biodigestor affected health. Two women had two responses.

Table 7: Perceived Effects of the Biodigestor on Health

	Eliminate the Contamination of the Air by Smoke	Minimize the Contamination of the Water by Excrement and Chemical Fertilizers	Minimize the Insects surrounding Animal Corrals
Frequency	5	4	1

All of the perceived effects above are supported by other research on the topic of biodigestors and the health of the family. The elimination of smoke associated with the use of the biodigestor causes the reduction of health conditions including headaches, nausea, burning eyes, respiratory tract infections, and dizziness ("Benefits for Households"). Water contamination is also reduced because the biodigestor treats the excrements and eliminates the need for chemical fertilizers, which may runoff and contaminate water and food sources. These sources of contamination have been linked to gastrointestinal illness, particularly diarrhea. Finally, the reduction of insects can be explained by the effluent's lack of an odor, which does not encourage insect propagation. In consequence, an increase the quality of life and a decrease in the risk for vector-borne infectious diseases for those who are responsible for subsistence livestock care, which is a duty primarily actualized by women and children, can be experienced. Essentially, the biodigestor seems to clean the air, water, and corrals for many of the women, but according to the responses in table 6, not for all.

4.4 Sustainability

Below, the chart shows the current state of the biodigestors at the time of the interviews.

Table 8: The Current State of the Biodigestor

	Functioning Well	Limited Function	Not Functioning
Frequency	7	2	2

A woman who answered that her biodigestor was not working a full capacity admitted that she did not have time to clean and properly maintain it. The other woman with the same response did not know the source of the problem, but she hoped that it would be able to function for longer periods of time with aid from the PDC. Both women who answered that their biodigestores were not functioning did not know the source of the problem either, but one stated that Luis—the engineer at the PDC—would come to fix hers later that week.

On average, the women who stated their biodigestors were functioning well spent 1 hour and 49 minutes on maintenance per week. For those who said their biodigestor was

not functioning at capacity or was not functioning at all, the average maintenance time was 1 hour per week.

The table below shows parties that received training from the PDC about the biodigestor use and maintenance when the technology was installed. Six women expressed that two groups have received training, and one woman said three groups received training.

Table 9: Family Groups who Received Training on Maintenance and Use

	Self	Husband	Male Children	Female Children
Frequency	9	11	3	0

One of the women said that she was not living with her spouse at the time of the biodigestor installation and never received training. All of the women who received training said that it was useful.

Among the women who received training in the use and maintenance of the biodigestor, the average maintenance time per week was 1 hour and 38 minutes and 67.0% of their biodigestors were functioning well. Both of the women who did not receive training stated that they did not spend any time on biodigestor maintenance during the week and between the two, one was functioning well, a rate of 50.0%.

Table 10 demonstrates the source of repair for the families when their biodigestors are not functioning at capacity.

Table 10: Source of Repair

	Self	Husband	Neighbor	EARTH Faculty or Student
Frequency	0	1	0	10

Among the 10 women (90.9%) who indicated that an EARTH faculty or student, all said that Luis—the engineer at the PDC—was responsible for the repairs when the biodigestor does not function properly. None of the women indicated that their community leader or any other neighbor aided in repair or maintenance.

V. Discussion and Recommendations

5.1 Daily Life

5.1.1 Logic

Conclusion 1: Biodigestors improve health and limit deforestation because they do not require wood.

A. The flame produced by the biogas is not as hot as that produced by wood

Conclusion 2: The biodigestors do not save cooking time.

5.1.2 Suggestions

Tables 1 and 2 indicate that for the majority of households, the biodigestor has succeeded in becoming an integral source of energy for cooking, thus alleviating some

dependency on wood and purchased energy sources—pinnacle goals of the project. However, as demonstrated from the discrepancy between hours spent on cooking and the hours of biogas accumulated per day, there is still room for improvement. The collected data shows a great diversity in available time cooking with biogas per day, ranging as low as 2 and as high as 9 hours.

The slight positive correlation seen in Chart 1, which relates the hours of maintenance per week and the hours of accumulated biogas per day, may suggest that as more time is inputted into cleaning and maintaining the biodigestor, the more hours of biogas that can accumulate and consequently be used for cooking, lighting, or water supply.

Unfortunately, however, considering biodigestors have not been shown to decreased the relative amount of time spent cooking after their installation and the many responsibilities women already have throughout the day, it may be unrealistic to suggest that more time be inputted into biodigestor maintenance without first confronting the lack of time saved for cooking after biodigestor installation.

According to a 2008 report by the National Biodigestor Programme, among biodigestor users in Cambodia, respondents reported saving around 20% more time on cooking-related activities, excluding the collection of wood, after their biodigestors' installations because biogas is quicker and easier to cook with than wood (18). However, according to several women interviewed in this study, the flame produced by the biodigestor is not sufficiently hot to reduce cooking time and occasionally even lengthens the cooking process. No literature could be found to substantiate these claims, however.

In consequence, a study must be conducted to determine if the biodigestor's flame is, in fact, not as hot as that produced by wood and if so, why that is the case. Only after this information is determined will a suggestion to reduce time spent on cooking be realized and consequently allow for more room for additional time spent on biodigestor maintenance and consequently, improved timesaving outcomes.

5.2 Economy and Health

5.2.1 Economy Logic

Conclusion 1: Greater input of biomass results in more available biogas.

A. Decreases need for supplemental energy sources such as wood, electricity, and propane cylinders.

B. Electricity and propane cylinders cost producers additional money.

Conclusion 2: More biomass saves money.

5.2.2 Health Logic

Conclusion 1: Greater input of biomass results in more available biogas.

A. Decreases need for supplemental energy sources such as wood, electricity, and propane cylinders.

B. Decreased need for wood results in less smoke in the house.

C. In-house smoke is correlated to respiratory disease and other health consequences.

Conclusion 2: More biomass improves health.

5.3.3 Suggestions

For many of the families, it is clear that use of the biodigestor is correlated to reduction in spending on propane gas for cooking and improvements in health and quality of life. Each of these benefits can be correlated to the amount of biomass available to the system: more inputted biomass results in greater methane capture and thus more energy available for use. In consequence, to further augment both economic and health benefits for the producers, it is evident that increasing inputted biomass is essential. This additional biomass is unlikely to be made available through additional animal excrement, however: typically, producers will sell all of their mature pigs during holiday seasons to maximize income, leaving them with only piglets' wastes to feed the biodigestor. In consequence, animal excrement cannot be expected to supply the need and thus other viable options need to be identified.

Incorporation of human excrement into the influent is a viable way to not only increase available biomass—and thus the existing health and economic benefits—but also to add a new health benefits to the existing ones listed in Table 7. Connecting the latrine to the biodigestor has the potential to improve household sanitary conditions and reduce food and water contamination from human wastes, as seen through biodigestor toilets' role in reducing the spread of cholera in Haiti ("Biodigestor Turns Waste into Fuel"). However, resistance from the farmers may affect its implementation, as many cultural taboos exist for the use of human waste. A lack of education also may promote resistance: one woman—a leader in the community—expressed concern that different, more harmful types of bacteria and parasites were present in human excrement (Universidad EARTH 9). As a result, this approach must be introduced to the community and households gradually through both education and experience: much like how EARTH introduces producers to the biodigestor technology by a tour of the University's working biodigestors, a point could be made to demonstrate and explain how the biodigestor adjacent to the cafeteria is powered by the students' waste from the neighboring dorms' bathrooms. This may encourage a greater understanding of the safety and potential of this unconventional influent source.

If too much resistance is met, however, another strategy for increasing biogas production is co-digestion. Co-digestion is a mechanism that increases methane production and increases the quality of biogas by treating different types of wastes simultaneously. In a study conducted in 2009 at EARTH, Stephanie Lansing investigated the consequences of co-digesting swine manure and cooking grease and found that just a 2.5% addition of grease increased methane production by 124%; this occurs because carbon atoms in lipids have more negative oxidation states than other macromolecules and because lipids are more difficult to hydrolyze. This reduces the pH in the digestion environment and consequently increasing methane yields (2 and 11). Doubling methane production in this way has great potential increase biogas levels and thus decrease dependence on wood and purchased energy sources, paving way for more economic and health benefits to be realized at the household level.

5.3 Sustainability

5.3.1 Logic

Conclusion 1: Women's training increases the likelihood that the biodigestor is functioning at capacity.

A. Women who received training spent an average of 1 hour and 38 minutes more on biodigestor maintenance every week.

B. More time spent on maintenance is correlated to more hours of biogas produced each day.

C. More hours of biogas produced reduces dependence on purchased energy sources and wood for cooking.

Conclusion 2: Women's training improves health and saves money.

5.3.2 Suggestions

As women's training seems to correspond to improved biodigestor condition, I believe that the PDC should mandate women's participation in the biodigestor installation and training process. Direct beneficiaries of biodigestor, women are likely to take great pride the technology, and this was evident through my conversations with them: many raved about the impact the biodigestor had on their lives and spoke of their emotional connection to it. These feelings can be channeled into an interest and a knowledge of the biodigestor that men may lack, as they may not interact with the new technology with the same frequency as the women. In consequence, women may be better beneficiaries of training than their spouses.

However, over-reliance on EARTH faculty and students for biodigestor maintenance and repair seems to exist regardless of proper training. In consequence, it is essential that a future study determine what factor or factors play into this dependence. For example, inadequate training or lack of economic or physical resources or time may all lead to this outcome. In any case, according to BRAC's theory of development, self-reliance is essential to sustainability, and the benefits derived from this technological intervention should not be dependent on the continued presence and availability of donor subsidies (Lovell 25). Patronage jeopardizes this. As a non-profit institution, EARTH and its programs like the PDC are vulnerable to economic downturns and donor pullouts. If funding was cut to biodigestor repair and maintenance, the families may not be self-sufficient enough to keep their biodigestors functioning, and thus their economic and health levels may fall again. To prevent this from occurring, dependence on the University must be reduced. This may be achieved through requiring participants to pay for a portion of the initial installation and/or for the repairs, much like many of BRAC's successful rural development programs. For example, the initial cost of the biodigestor could be adjusted for the family's financial state at the time of installation, and then for a period of six months to a year, EARTH faculty and students could help maintain and repair the biodigestor for free on the condition that a family member be present and active in the process. After the time window closes, the University could begin charging the family for these services in hopes that this would encourage self-sufficiency.

If not self-sufficient, community-sufficiency would be ideal over University-dependency. This could be achieved through improved training for several community leaders on biodigestor repair and increasing other community members' awareness of their available services. If sufficiently trained, there is potential for a community leader

or leaders to form a small microenterprise based on biodigestor repair and maintenance, which has the potential to improve the local economy and reduce EARTH's presence in the sector.

VI. Personal Reflection

Two months later, it is still hard to find words that scratch the surface of the true impact my internship has had on my beliefs, perspective, and life. But I feel it—the overwhelming feeling that bubbles in my chest every time I set foot in a grocery store with hundreds of yogurts, produce varieties, and sliced deli meats; the focus and purpose that overcomes me when opening a textbook; the conflicting emotions than run through my mind when I drive by miles of cornfields —I feel the difference.

With only previous research experience in a closed laboratory setting, I was ignorant to the complexities of qualitative research prior to my arrival at EARTH. I assumed that interview answers would be clear-cut; the solutions, simplistic and accessible. I knew that women would have a substantial impact on household food security, and I naively assumed it would be easy for me, an outsider, to break through the cultural norms and traditions to improve their lives and health. Clearly, complexities I never foresaw arose, contributing to a newfound appreciation for the art of international and community development projects. However, in contrast, my understanding of public health measures was simplified in the sense that interventions do not have to be revolutionary and intricate. Like the biodigestor, sometimes the most low-tech, accessible solutions can have more dramatic impacts on community health than involved infrastructure and expensive technology, which may not even be wanted.

Language, too, became an incredible source of growth. After I arrived on campus, I quickly found out Fabián, my supervisor, spoke no English, a barrier I never anticipated. This challenge evolved into a blessing over the course of my internship, however, as my improved Spanish language skills over the first several weeks allowed me to be able to communicate directly with the women I was to interview and thus eliminated a potential barrier between us. Although my Spanish was not fluent enough for unhindered conversation, the experience underscored the necessity of language proficiency in any international research I may do in the future for increased understanding of culture and belief systems.

Furthermore, confined mostly to book learning and lectures throughout my high school and college experience, the experiential learning at EARTH enhanced my views of education. Within days of my arrival, I stepped on the farm alongside students and local producers for the first time in my life, and for at least one day every week throughout my stay, I was able to experience the life of subsistence farmers. I planted papaya trees, composted, weeded the fields, built biodigestors, worked on a banana plantation, and even helped pluck, carve, and roast a duck. I lived without air conditioning, hot water, and a western diet for two months. These experiences may be simple, but they have allowed me a rare window into what real poverty and food insecurity look like; these experiences have allowed me to empathize with the people for whom I want to advocate and research. Even my days in class with the EARTH students transformed my education experience. Unlike many of my classmates, the EARTH students learned with a purpose: this was both externally motivated through the

University's experiential curriculum, but also internal, as after each fifteen minute lecture by a professor, thirty minutes of questions would ensue. These students learn so they can improve their own rural communities back in Lebanon, Mozambique, Bolivia, and Guatemala among others. This is a perspective I need to adopt in my own education: I need both practical experience and a purpose to even begin to follow in Dr. Borlaug's footsteps.

Lastly, this concrete experience has altered my perspective. Through this opportunity to have conversations with students, faculty, and other interns about food—the topic I am most passionate about—my once solid views on organic and conventional agriculture and sustainability have grown. Some have grown in merely depth of understanding; some, transformed entirely, convicted by the fact that the people who have given their whole lives to the land understand the issues more than I ever could. But my greatest perspective shift occurred in a conversation I had with a student one of my final nights still resonates: he asked me to describe my goals over the next few years, and I answered that I wanted to get good grades, go to good graduate school, and do some high-profile research that changes the world. I asked him the same question. He answered, "I want to make enough money to move my mother and sister out of our bad neighborhood back home in Mexico." Humbled, I have returned not to fight to change the world for my own glory and ideals—for likely it will change in spite of me. Rather, I will remember Miguel's powerful words, Katy and Carlos' patience in helping me learn to compost, and Luz's grace with my clumsy Spanish, and fight not just for them, but with them.

VII. Works Cited

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VIII. Appendix

Cuestionario

Introducción: la presente investigación sobre biodigestores que se realiza en su comunidad es para descubrir espacios para mejoramiento de las actividades del PDC en este tema.

Instrucciones: sírvase contestar lo más honestamente posible acerca de las preguntas que se le formulan.

I. Introducción

1. Nombre:_____

2. Años:_____
3. Más alto nivel de educación
[ ] Nada [ ] Primaria [ ] Secundaria/colegio [ ] Universidad [ ] Otro:_____
4. Cuánto tiempo tiene de vivir en Las Floritas: _____
5. Principal fuente de ingresos:_____
6. Fuentes secundarias de ingresos:_____ _____
7. Cocinero principal del hogar
[ ] Usted [ ] Su esposo [ ] Sus niños [ ] Sus niñas [ ] Otro:_____
8. Horas al día dedicado al cocinar:_____
9. Principal fuente de energía para cocinar:_____
10. Fuentes secundarias de energía para cocinar:_____ _____
11.Tiene animales en su finca? Cuáles?: _____
12.¿Usos primarias y secundarios del BG? _____ _____
_____
13. Horas del biogás que acumula por día: _____
14. Tiempo de utilización al biodigestor: _____

II. Tiempo
1. Antes de que el biodigestor se instala, cuántos horas al día cocinaba? _____
2. Ahora, cuántos horas al día cocina? _____
3. ¿Cómo pasa este tiempo libre? _____ _____
_____ _____
4. Cuánto tiempo que usted gasta en el mantenimiento de biodigestor al semana? _____

III. Salud
1. Antes de que el biodigestor se instala, cuántos días al mes su salud se interfería con su trabajo o responsabilidades diarias? _____
2. Ahora, cuántos días al mes su salud se interfiere con su trabajo o responsabilidades diarias? _____
3. ¿Piensa usted que el BG está relacionado con la salud de la familia? ¿De qué manera?

IV. Dinero
1. ¿Cuánto gastaba en electricidad para cocinar al mes antes de que el biodigestor se instalaba? _____ (recibo de electricidad)
2. ¿Cuánto gasta en electricidad ahora para cocinar al mes ahora? _____
3. ¿Cómo usa el dinero "extra"? _____ _____
_____
4. Quién toma las decisiones sobre cómo utilizar el dinero en el hogar?
[ ] Usted [ ] Su esposo [ ] Los dos [ ] Otro:_____

V. Sostenibilidad
1. ¿Cuál es el estado del biodigestor ahora? _____
2. Si el biodigestor no está funcionando muy bien, quién le ayuda a arreglarlo?
[ ] Usted [ ] Su esposo [ ] Un/a vecino/a [ ] Funcionario o estudiante de EARTH
[ ] Otro:_____

3. Quién en su familia ha recibido formación de la Universidad para la mantenimiento y uso del biodigestor?
[ ] Usted [ ] Su esposo [ ] Sus niños [ ] Sus niñas [ ] Otro:_____
4. Si usted ha recibido formación, piensa que la formación haya ser útil? _____
5. ¿Qué tan costoso (dinero y trabajo) siente usted el mantenimiento del BG?

VI. Varios
1. ¿Cómo siente que ha impactado en su vida tener un BG?

2. ¿Cómo ha impactado a la comunidad tener biodigestores?

3. ¿Qué problemas se ha encontrado teniendo un BG en su finca?

4. ¿Tiene otros comentarios?