
Jordan Atnip, Jillian Flavin, Joseph Friedman, Elana Curry, Radhe Patel, and Thomas Decker
Abstract
Monte Verde, Costa Rica has experienced an influx of capital associated with environmentalism and tourism in recent years. This has begun to shift the economic focus of the Zone from agriculture to tourism. Farm waste management practices sit at a unique crossroad between shifting food production patterns and increasing concerns of environmentalism and the promotion of eco-tourism. Using methodologies from medical anthropology and environmental engineering animal waste treatment practices in Monte Verde were investigated. Interview (n=10), focus group (n=2), and survey data (n=49) were collected in order to assess current practices, as well future intentions of producers who manage animals. Ethnographic data were also used to assess how perceptions of farm impacts are changing in the region. Community informants with relevant experience defined aspects of animal waste management they would like to see improve in Monteverde. Where possible, quantitative and observation data were collected in order to explore the concerns raised. Interviews with local experts and literature research were conducted in order to identify potential practices and technologies that could facilitate the desired changes.

Keywords: Animal Waste Management, Anaerobic Digestion, Monte Verde, Costa Rica.

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Introduction

This study was conducted as part of the 2013 University of South Florida Globalization and Community Health Field School, working in collaboration with the Monteverde Institute, and funded by the National Science Foundation. The group is composed of six students from different fields of study. From late June through July students conducted community based research in Monte Verde, Costa Rica using methodologies from applied medical anthropology and environmental engineering.

The Monte Verde Zone, or la Zona, is located in the northern region of the Costa Rican province of Puntarenas. It includes the village of Monteverde, originally settled in the 1950s by Quakers, as well as the surrounding towns. Despite the heterogeneity of social and geographic elements it describes, the term “the Zone” is used in this study for culturally salient meaning it conveys locally. It indicates Santa Elena, the economic center of the region that largely caters to tourism, as well as the surrounding dairy-centric villages spread throughout the “milk shed”, which sprawls over the mountainous highlands near the continental divide.

The region has received significant international attention recently, both as a tourist attraction, and a location of nature conservation efforts. The influx of capital associated with environmentalism and tourism has begun to shift much of the economic focus of the Zone from agriculture to tourism. Farm waste management practices sit at a unique crossroad between shifting food production patterns and increasing concerns of environmentalism and the promotion of eco-tourism. In this context, animal farm waste practices were investigated after being identified as important areas of concern by community partners.

Goal

This study attempted to explore waste management practices in the Zone, a theme identified as important by community partners. In order to approach the issue in a holistic manner, three research questions were identified. What are the current community perceptions of farms and their impacts on the environment? What wastewater treatment practices are currently used, and how successfully? What are

4 ibid.
5 ibid.
other methods by which waste can be treated in the context of Monte Verde? What barriers prevent the community from implementing change in the Zone?

**Methods**

The data for this report was collected using a mixed methods approach combining methodologies from environmental engineering and medical anthropology. Both qualitative and quantitative data were gathered in order ground results in various perspectives. This “triangulation” of data was used to generate a holistic perspective.

A combination of formal interviews (n=10), structured interviews and questionnaires (n=49), focus groups (n=2), and free listing/pile sorting activities (n=9) were used in order to gather data to a) assess community perceptions of animal farms, b) highlight current waste management practices, c) define areas of desired change and potential practices and technologies that could facilitate the desired changes, and d) explore barriers to the implementation of change as well as potential solutions to these barriers.

**Free listing and Pile Sorting**

Members of the Santa Elena community (n=9) were presented with topics, and asked to list words that they associated with the subject. This exercise was a primary measure, serving to generate themes and areas of interest within our research areas that were further explored with subsequent investigation.

**Structured Interviews and Questionnaires**

A total of n=49 structured interviews and questionnaires were administered; n= 28 at the San Luis community center, and n=21 at the weekly farmer’s market in Santa Elena. Survey instruments used in San Luis and Santa Elena can be found in Appendices I and II respectively. Data analysis was carried out using SPSS.

**Semi-Structured Interviews**

A total of n=10 interviews were conducted with members of the Santa Elena and San Luis communities; n=6 with agricultural producers, and n=4 with other community members.

**Focus Groups**

Focus groups of community members were conducted in both San Luis and Santa Elena. Groups discussed themes of: community perceptions of animal farms, waste treatment practices, and perceptions of environmental contamination in the Zone. Participants were recruited with assistance from the students and faculty of the Montverde Institute.
Ethnographic Investigation
Participant observation and informal interviews were used throughout the data gathering process to gain a holistic understanding of the research areas. Ethnographic note taking was used, and field noted were coded with grounded theory analysis when possible.

Results and Discussion
Community Perceptions of the Impact of Animal Waste
In general community informants did not tend to see animal farm waste as an exorbitant environment issue. Only n=1 of 46 survey participants believed farms had a “great” impact on the environment (figure 1). contrast, n=14 (30.4%) respondents indicated that they have no effect.

Various aspects of the perceived effects of animal farms have further explored with structured and semi-structured interviews in order to delineate the fairly nebulous concept of “affecting the environment”.

Negative Associations
Negative sentiments associated with animal wastes were stated in environmental, social, and aesthetic terms. Concerns were expressed about the quantity of water used to clean the farm and maintain the animals. When asked to free-list words associated with animal farms, n=5/9 respondents gave water as a related element. In surveys 73.5% of individuals reported the belief that farms cause river contamination to some extent, and interview data further support this idea. Quantity of water use was an important facet, and several informants felt that “when a lot of water is used, a lot of water becomes contaminated.” Odor pollution is also an important negative association. One informant considered odor generated from pig farms as a “public health issue,” and one local mother said that it is “upsetting to children.” Several individuals felt that odors from animal farms constitute a form of environmental pollution.

Figure 1: Perceptions of the extent to which animal farms affect the environment.
Positive Associations

One highly positive trend noted was the possibility to aprovechar, or take advantage of, animal waste. Many survey respondents conveyed the sentiment that animal waste was a great opportunity to generate biogas and organic fertilizer. Several respondents felt that if well-managed animal waste has no impact on the environment. Many individuals explained that since animals "are part of nature," farms are environmentally beneficial. A focus group participant stated in no uncertain terms that “with good management, farms help the environment a lot”.

Perceived Relative Importance of Farm Impact

According to survey data, most community members perceive that farm animals contribute “little” or “some” to river contamination. When compared to other potential contaminants, the data suggest that this effect is conceptualized as less intensive than that of chemical fertilizer, domestic inorganic trash, grey water, black water and factories (figure 2). The only elements viewed as less contaminating to the river were tourism and domestic organic waste.

![Average Perceived Degree of Contamination](image)

Figure 2: Relative Perceived Degree of Contamination for Several Factors

Contextualizing Perceptions of Animal Farm Impact

Visibility of Pollution

Several informants discussed the visibility of animal farm pollution in relation to its perception by the community. In structured and semi-structured interviews garbage was consistently ranked as a more substantial pollutant than animal farms. When asked about this phenomenon, one community informant suggested, "you don’t see cows pooping trash bags," liquid waste is far less glaring than the trash bags attributed to the impacts of tourism on the Zone. Farm waste may also be less visible to many community members due to their distant location from residential areas. When asked about the issue, one community member reported “I am not near
a farm... it does not affect me.” The secluded nature of farms may reduce their perceived impact on the environment.

**Smallholders’ Relative Merit to “Pollute”**

In focus group discussions community members claimed to be more accepting of the pollution generated from small-scale animal farms over other larger entities that contaminate. In the words of one individual, small farms are seen adding to “micro-economy” in the Zone, in their effect of providing jobs and local organic products for community members. In this way small farms reintroduce capital into the community, rendering whatever environmental contamination they may produce “more tolerable.” Using this concept, informants contrasted small farms to larger agricultural operations, which were seen as having a different economic effect on the community. As one community member explained, “the money doesn’t stay here and the profits are centralized in a few individuals.” Therefore, the sentiment is that large farms use community and environmental resources, like land and water, but do not benefit the community as small farms do in return.

**Changing Conceptions of Environmental Harm**

Several community informants felt the way that people in Monte Verde conceptualize farming practices is changing. One individual claimed that historically there has been a longstanding association between farms and economic prosperity. He discussed this idea in the context of the Spanish word for cattle, *ganado*. The word comes from the Spanish verb *ganar*, or “to win.” In this way, he explained, “having more animals was seen as more prosperity for the family, regardless of the larger quantities of waste or pollution that might be involved.” Nevertheless, local understandings of the environmental aspects of farms have been changing.

Monteverde has been host to a variety of external influences; from Quakers in the 1970s to environmentalists in the 1990s, the region has experienced multiple groups of outsiders in recent decades. Several interview participants discussed how various groups of international volunteers, students, tourists, and business owners have brought new ideas to the Zone. This influx of perspective, they explained, has influenced environmental priorities, and practices. One educator from the community discussed how the exchange of ideas his students are exposed to from international volunteers affects the way they understand environmental issues. He attributes much of the change his school has experienced in recent years to this importation of external concepts.

Foreign ideas also have influence in the community due to their economic import. As the zone experiences an influx of capital from “eco-tourism”, catering to the sentiments of outsiders has serious financial benefits. Many farms profit from providing “eco-tours” to international visitors, and advertisements for these sorts of expeditions are ubiquitous in Santa Elena. As one farm owner, who has cabins and other touristic services on his property explains, “When people think of Monteverde,

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7 Vivanco, Confronting Environmentalism, 6.
8 Ibid, 155.
they think of nature, beauty, and harmony. It’s the only way to establish ourselves and to create a good market. It’s like a brand for Costa Rican tourism.” When tourists come to Monte Verde they have certain expectations as to what they will experience as part of eco-tourism, and these preconceptions have an effect on the presentation of natural spaces in the Zone. One shopkeeper felt that through interacting with foreign tourists, he “came to value the environment,” and in this way foreign capital catalyzes the adaptation of external ideal, at least superficially.

As foreign ideas and capital wash over the Zone, they affect the way that people interact with ideas of “nature” and “environmentalism” on a daily basis. These changing conceptions impact the way that people think about animal waste treatment practices in the Zone.

**Current and Future Wastewater Treatment Practices**

Wastewater management methods currently used in the Monte Verde region were identified using interview data. The frequency of various practices was assessed using survey data, and the results can be seen in figure 4. Each treatment method was subsequently explored using survey, structured and semi-structured interview data. Farmers were also asked about which treatment practices they were interested in pursuing in the future. Interest in the potential utilization of various treatment practices can be seen in Figure 4 overlaid on top of current usage patterns for comparative purposes.

![Figure 4: Interest in Various Animal Waste Treatment Methods Among Individuals with Farm Animals in San Luis](image)

**Field or Pasture Application**

Applying waste to fields was the second most frequent method of waste management reported in survey data (n=11/21), in interviews many respondents also reported using the practice. Perceptions of this practice were mixed; many informants felt it was acceptable and did not pose an ecological concern, as waste is a “natural” part of the life cycle. One older farmer explained that applying waste to
fields was simply “giving back to nature what was taken out” for agricultural purposes. Most farmers felt that using animal waste on their fields was an excellent way to take advantage of organic material. Several farmers who use animal waste on their pastures reported that they noticed a great improvement in the quality of their grass after waste application. As one farmer described, the general belief is that waste “naturally turns to organic fertilizer in fields,” and therefore represents an economic benefit.

Despite the benefits, some individuals expressed concerns about waste being put on fields that were located close to water sources or residential areas. They felt that farms located near water sources could potentially contaminate the environment as rain often washes waste into rivers. One farmhand felt that although the river located close to his farm was usually very clean, during the rainy season preventing contamination from waste carried by rainwater was “nearly impossible.”

**Wastewater Retention Tanks**

The use of a retention tank system to hold waste prior to dispersal is a common practice for medium and large-scale farmers. This usually involves collection pipes to carry wastewater from barns to the tank, a pump to push the waste through the system, and pipes carrying wastewater slurry to the fields. Some farmers felt that the electricity or fuel required to pump waste onto fields was a major drawback to the technique. The process can also be time consuming if manual labor is required for waste distribution, and one field hand described the many hours he spent moving tubing from pasture to pasture. In several observed retention tanks, only about two days of water could be accommodated. Therefore, treatment of the waste is minimal. Nevertheless, these systems have the benefit of effectively storing and dispersing wastewater with precision, and most farmers interviewed were overall happy with their tanks performance. Despite the positive views of farmers who use such systems, there was very little interest among other individuals in implementing them to manage their own animal waste. As demonstrated in figure 5, only two individuals, not currently using retention tanks, expressed interest in implementing such a system, compared to eighteen individuals who were not interested. This lack of interest was expressed in the comments of farmers, calling retention tanks “unpleasant” due to odor and ineffective in their lack of actual treatment of waste.

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*Facultative Lagoons*
A facultative lagoon is essentially a man-made open-air pond, which is used as a space for sedimentation and biological breakdown to occur.\(^9\) Waste is fed into the system on one end, is retained in the system for a period of time, and is then discharged out the other end into a receiving body of water.\(^10\) Although lagoons are found in some industrial and farm settings in the area, the public mostly considers these lagoons to be ineffective. One farmer felt that wastewater lagoons “don’t actually do anything. They are mainly an excuse for factory owners and farmers to dump waste into rivers without actually treating it.” In semi-structured interviews most informants were uninterested in implementing a lagoon on their property, explaining they “take up space,” “smell bad,” or “pollute rivers.” One farmer who had previously considered a facultative lagoon as a potential wastewater treatment method decided against its implementation due to the large space requirement and long retention time. This trend is reflected in the survey data, in which only n=2 farmers would consider implementing a lagoon on their property, while n=17 were uninterested (Figure 6). Despite the negative sentiment expressed by most informants, the interview respondent who had worked with facultative lagoons were reportedly very happy with their performance. One individual highlighted the sustainability of one such system, arguing that as the lagoons used fish, shellfish and turtles to break down waste, it was an effective and natural method of waste management.

**Composting**

The survey data suggests that the most well entrenched animal waste treatment practice is composting. More than half of survey participants who have animals (n=12/20) already use the technique, and only (n=6/21) had no interest (figure 7). Many farmers reported using the technology with great success, and being overall “very satisfied” with the results. Several individuals described composting as one of the “best methods” for managing animal waste, as it leads to “less contamination” and better use of the nutrients in the organic waste.

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\(^10\) Ibid.
A variety of materials being composted were observed, such as food scraps, manure, and organic byproducts from other processes. Several coffee harvesters were also observed composting their coffee bean shells, using regular or vermicomposting, and reported it worked well for them.

Despite the overall enthusiasm for the technique, some producers did not feel that it was appropriate for their operations. One farmer who owned pigs described how it would be impossible for her to compost given the large degree of labor it would require to collect the semi-liquid waste. Aggregating the waste is regarded as the most intensive step of the process; therefore some individuals felt that composting is better suited for waste that is produced in one location, such as food scraps or coffee shells. Even for small amounts of waste, composting requires manual labor, and this may render it less desirable to farmers who have little free time, do not want to pay for labor, or have large operations.

**Biodigesters**

One area of interest to many parties in Monte Verde is the use of tubular polyethylene anaerobic digesters, commonly referred to as “biodigesters.” These systems are large cylinders made of polyethylene plastic sheeting (see Figure 8). They maintain an internal oxygen-depleted environment in order to facilitate anaerobic digestion processes. Wastewater slurry is added to one end of the digester and digested biologically as it moves through the system, usually for a period of 30+ days, depending on the characteristics of the site and waste. Slurry then exits the system from the other end as treated organic fertilizer, which can be applied to fields. The system also has the advantage of producing methane gas (usually referred to as biogas), which can be stored in tanks or bags and burned as fuel for cooking, electricity generation, or other purposes.

The community generally viewed these systems quite favorably. Although only n=3 survey respondents currently use biodigesters, n=10 respondents were interested in implementing one, compared to
n=8 people who were not interested (Figure 9). These data suggest that biodigesters are one of the most theoretically popular, albeit less implemented, waste treatment systems among our respondents. Interview data further support the idea that many people in the Zone view biodigesters positively. Several farmers frame a biodigester as a way of “taking advantage” of their animal waste. Small scale producers reported using biodigesters to treat waste products including: cow, chicken, and pig manure, animal blood, coffee shells, food scraps, and human excrement. Many individuals felt that biodigesters had a multiplicity of benefits, not only reducing environmental contamination, but also generating biogas and organic fertilizer. The methane gas generation aspect of the system was especially important to community members. On several occasions families who had biodigesters were enthusiastic to show-off there biogas-powered stove, explaining that they provided 3-5 hours of gas per day on average. As one individual shared “it’s so important that we make the most of our waste and extract biogas, before we didn’t know we could, but now that we know, we must.”

Local activists and entities have also supported this technology. Through their campus in San Luis, the University of Georgia (UGA, has played an especially dominant role in spreading the biodigester technology. UGA has worked with local farmers, providing information, support, and occasional funds for development of the technology. They have also implemented biodigester systems to treat the waste produced at their facilities. One local activist said that “[biodigesters are a] functional, simple, and inexpensive technology that acts to transform a problem for the community into an opportunity, in economic and environmental terms.”

Regardless of some respondents’ enthusiasm, a few agricultural producers shared problems they’ve had with biodigesters. One farmer feels that the system can be a “false promise”, because without sufficient education and support in terms of design, installation, and maintenance, failure is likely. He installed a biodigester on his farm after being “caught up in the local enthusiasm” for the technology, but had to scrap it due to poor performance. Another farmer shared her reservations; she feels that although the technology could be very effective for some regions, the climate of Monte Verde was too cold for it to work efficiently. She is interested in potentially using a biodigester, but is afraid that the significant investment such a system would require would go to waste if there was poor performance. She has “heard of many such systems failing in other places in Monte Verde,” and feels that she would have to see a system work in the high altitude climate of Monteverde before she would be willing to risk installing one herself.

Nevertheless, biodigesters remain a very popular and politicalized technology in the Zone. Several interview respondents who had tried to build biodigesters unsuccessfully reported that they were still very interested in employing the technology. The general sentiment conveyed from informants was that there is substantial social momentum as well as growing economic support for the development of biodigesters in the region.
Areas of Desired Improvement

Interviews with local farmers and waste management experts revealed several aspects of animal waste management practices that were considered desirable by some or all parties. Subsequent interviews as well as literature research also highlighted potential technologies and practices that could help address the concerns.

Reduction of Water Usage

As in many regions of the world, farmers in Monte Verde use water in large quantities to maintain a clean farm environment. Spraying down barns and other livestock areas allows farmers to clean without needing to employ extensive labor. Water is abundant and cheap in Monte Verde. Springs and rivers provide water for most farmers, a situation which results in a seemingly unlimited supply.

Nevertheless, as several farmers and experts shared, high water use does have consequences. The removal of water from natural sources upstream can impact wildlife, incite geological change, and decrease the water access of others downstream. Locally, the usage of high volumes of water generates a large quantity of waste that farmers must manage. The greater the volume of water used, the larger capacity an adequate waste treatment system must have. According to one environmental expert, as consciousness about waste treatment practices in the Zone grows, there is increasing awareness about the benefits of water use reduction. Some farmers reported working in this aim, and felt that it was important both in economic and ecological terms. The opinions of local waste treatment experts coincide with the farmers; one felt that “It’s not the water’s fault that it’s being used to clean animals, so we have to use it as little as possible. Reducing the quantity of water used is paramount, and it is the single most important step to take in improving waste management.”

Despite the level of awareness about the issue, barriers to water usage are still prevalent. Without water, waste management can be extremely labor intensive. Educational facilities often have access to free student and intern labor, which can make management practices requiring less water more feasible. In contrast, small farmers often feel they cannot afford to maintain hygienic facilities without frequent washing. Another concern is that by cleaning less, odor pollution can become a greater issue, potentially resulting in worsening relations with neighbors.

In order to reduce water use, one farmer discussed his decision to use high-pressure, low-volume nozzles on hoses used for washing. Some Producers involved in the research also add substances to barn floors in order to reduce odor, and allow for less frequent washing. This can include limestone, which pre-treats waste chemically before it’s added to a treatment system, or microorganism solutions, which accelerate digestion.
**Bokashi**

As discussed previously, odor was a major community concern in relation to animal farms. Perhaps not surprisingly then, respondents who manage animals generally felt that odor reduction was an important aspect of their waste treatment system. One technology that can improve odors is a liquid concentrate containing a slew of microbes that help breakdown waste, called effective microorganisms (EM). The Japanese researcher Teruo Higa invented this technology in the 1980s, and it has since been adopted and promoted by several academic institutions in Costa Rica. Bokashi can be applied to barn floors, which begins the process of breaking down waste and thereby reducing odor. The use Bokashi can therefore permit less frequent washing of barn surface, resulting in water use reduction.

The EM liquid is relatively expensive, costing approximately $250 for 100 liters of solution from local sources in Costa Rica. It can also be produced on-site at farms, and there is some support available in the form of starter kits and informational materials for farmers who wish to attempt the process. According to local activists who are promoting the technology, production is simple, and EM liquid represents an effective way for farmers to reduce odors, treat waste, and protect the environment.

**Improved Management of Whey**

In the Zone dairy farming constitutes a large portion of agricultural production. Much of this milk is used to produce cheese, and therefore whey, a cheese byproduct, is readily available. Whey is a white mixture containing about 6-7% solids, which is mainly composed of proteins and sugars.\(^{11,12}\) The BOD\(_5\) (a measure of organic content) of whey can range from 27,000 to 60,000 mg/L, which is equivalent to the pollution load of one hundred times the volume of common domestic wastewaters\(^{13}\). The treatment of whey is a tricky issue; its chemical composition does not allow for rapid breakdown in the environment, and its concentrated nutrients can heavily impact wastewater quality causing eutrophication and issues associated with rapid algal growth.\(^{14}\) Whey is perceived as a major source of water pollution in the Zone.

Some pig farmers in Monte Verde have regular access to whey as a food source for their animals, in some cases obtaining it for no cost above the expense of transportation. Farmers feed the pigs whey several times a day, and report that it helps the pigs "put on weight due to the high protein content." Many people viewed feeding whey to pigs as a great opportunity for pig farmers to take advantage of a "super contaminating" waste product while also reduce whey contamination of the river.

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\(^{13}\) Carvalho et al., 2004.

\(^{14}\) Ibid.
In order to prevent environmental degradation from whey, it must be fed to pigs in a conscientious manner, and the resultant manure managed with an adequate treatment system. A basic measure is simply for farms to take only the amount of whey needed for the pigs being raised\textsuperscript{15}. Although this seems simple, interview respondents report that occasionally excess whey is simply allowed to drain off into local bodies of water or fields when animals cannot consume all of it. One farmer avoids routine spillage by using storage tanks that connect directly to feeding troughs. This reduces labor demands and accidental spills, and provides more accurate whey consumption control.

A list of associated literature with the treatment and use of whey can be found in Appendix V.

**Improved Anaerobic Digestion Technology**

The anaerobic processes that occur in a biodigester happen naturally in any oxygen-depleted environment, and are utilized for wastewater treatment all over the world.\textsuperscript{16} Although tubular anaerobic biodigesters represent the cheapest form of anaerobic digestion technology, in many respects they are not suited to some of the waste treatment challenges found in Monte Verde. They are fragile, and are vulnerable to the harsh winds and rain of the Monte Verde climate. Additionally they may not function as effectively in the colder seasons found at higher altitudes in the Zone. Tubular biodigesters also have a retention time of 30+ days, which means for farms with large quantities of wastewater the digester size has to be extremely large for effective treatment to occur. This section explores other anaerobic reactors that, although have higher installation costs, may be better suited for certain producers in the Zone.

**Anaerobic Baffled Digester**

One system that can be effective in Costa Rica and the Monte Verde Zone is an anaerobic baffle reactor (ABR). The system utilizes multiple chambers to break down pathogens and organic materials. The system has liquid waste retention time of only 4-12 hours, which means that reactor size can be much smaller than a tubular biodigester for the same quantity of water treated.\textsuperscript{17} ABRs are built from durable materials and consequently do not require large amounts of maintenance compared to systems constructed of polyethylene. The systems may have a higher installation and construction cost than other less extensive systems, but they last longer, can be smaller, and may perform better.

\textsuperscript{15} According to Wendroff, a pig’s diet should be at most comprised of 30% whey. Ex. for a pig between 80 and 130 pounds, the amount of whey should not exceed 2.25 gallons.

\textsuperscript{16} Anaerobic digestion has three stages: hydrolytic in which complex organic materials in the waste substrate are broken down, acid forming, where simple sugars produced in the first stage are reduced to simple organic acids, and finally methanogenic where acids, hydrogen, and carbon dioxide are converted to methane and carbon dioxide using methanogens (Xiaoqi Zhang Chapter 5 Anaerobic processes).

\textsuperscript{17} Zhang, Xiaoqi. “Comprehensive Water Quality and Purification.” University of Massachusets Lowell.
**Construction**

The system shares some design features with tubular biodigesters. Wastewater flows in the inlet located below the reactor water level, facilitating a process in which heavier organic matter sinks while lighter material floats to the top (figure 10). As wastewater passes through each chamber, barriers that are connected to the sides of the tank force it through a series of sludge blankets located at the base of each compartment. In the sediment layer, solid particles are caught and interact with the bacterial elements of the activated sludge. Methane gas is produced throughout the process, and it is collected at the top of the unit. Although reactors with various numbers of chambers can function, studies have shown that reactors with 4 or 5 chambers work the most efficiently and produce the most biogas.\(^{18}\)

Once an ABR is built, activated sludge seed needs to be added from another anaerobic reactor, which can be obtained from a tubular biodigester or industrial waste treatment plant. At full potential the system requires minimal interaction and wastewaters with a wide variety of characteristics can be treated.\(^{19}\) One important caveat for this system is that the wastewater needs to enter the system at a constant rate.\(^{20}\) Therefore, a storage system, such as an equilibrium basin, is necessary to release waste to the digester slowly.

**Design**

Working with a local expert in digester construction, locally available materials were identified that could be used for construction of the reactor. Similar systems have been built in Costa Rica using concrete and rebar, with a ceiling of zinc and iron. Using calculations found in *Decentralized Wastewater Treatment in Developing Countries* by Ludwig Sasse a hypothetical case study was conducted using rough estimates of a medium farm in Monte Verde. The case study can be found in Appendix I.

**Upflow Anaerobic Sludge Blanket**

Although the ARB system is a very effective technology in many cases, it may not be the most appropriate solution for all waste management situations. Another system that would be feasible for the Monte Verde Zone is an Upflow Anaerobic Sludge Blanket (UASB). The system is similar to an ARB, differing mainly in that it uses less

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ground space as it stands upright, and requires more regular sludge removal. More details about the reactor can be found in Appendix II.

**Improved Wastewater Reuse**

As previously discussed, contamination from animal farms is seen by many members of the community as a major contributor to river contamination in the Zone. Some farms that are located near residential areas avoid spraying waste onto fields, in order to minimize odor. This has the effect, however, of causing non-uniform dispersal patterns onto fields. This, along with heavy rainfall in the wet season, and the steep slopes of many pastures, leads to run-off into surrounding forest areas and bodies of water. Due to a lack of pre-treatment, this run-off poses a risk to the community and the environment.

**Subsurface Wastewater Infiltration System**

Used in conjunction with a waste treatment system, a subsurface wastewater infiltration system (SWIS) can be used to disperse wastewater in a slow and even fashion, to avoid runoff. SWIS are widely considered to be the treatment system of choice in rural unsewered areas. A SWIS begins with a distribution box that is connected by tubing to the main treatment reactor. This box serves to disperse wastewater into underground pipes, which are buried throughout pastures or fields. The buried pipe is completely surrounded in a porous material such as gravel, to provide initial space for infiltration, and to prevent erosion (figure 11). The gravel is lined with geofabric that would permit water to leave the system while preventing soil from clogging essential pore space.

Allowing liquid waste to enter the gravel drainage promotes natural filtering, as bacteria growing in this space will decompose the harmful bacteria. As the waste infiltrates into the soil, oxygen is reintroduced into the liquid, while pathogens are removed. The underground dispersal utilized in SWIS both reduces odors, and slows water movement through fields considerably, allowing the soil to retain nutrients for improved plant growth.

The main barrier for the installation of a SWIS, is the considerable financial investment involved in installation of the pre-treatment system and underground

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22 Ibid.
pipes. A pre-treatment system is necessary to prevent heavy solids from clogging the pores of the gravel infiltration layer. These two requirements are examples of the financial barriers that farmers in the Zone face. Nevertheless, if overcome, a SWIS can be an excellent solution for the irrigation problems faced in the Zone.

**Improved Overland Flow**

A popular method of wastewater dispersal for many farms in the Zone is overland flow. This simply entails using pipes or hoses to distribute waste on the surface of pastures, allowing it to infiltrate the soil from above. If SWIS is not a feasible solution, then properly managed overland flow can be an effective alternative.

**Surface Spraying**

A common method of overland flow distribution involves the use of sprinkler surface spray systems on fields. This does however require that pastures are left uneaten for at least 15 days according to Costa Rican law. This technique is usually used in concert with a filter during spraying, as well as waste pre-treatment. Spraying ensures uniform waste distribution upon pastures, which reduces runoff. Anaerobic digestion can be used to minimize odor, which can be an issue when waste aerosolizes in the sprayer.

**Berms and Swales**

One technique that can help slow the movement of wastewater over pastures is the installation of rows of rock berms, which are lines of stone mounds that follow contour lines going down the pasture. The rocks allow for increased infiltration time by establishing a barrier that slows water movement over soil. Given that the ideal slope for overland flow is 2 to 8%, and many pastures in Monte Verde have a grade of over 20%, these measures can help counteract the inherent tendency towards run-off. Berms can also be installed in strategic locations in order to ensure no wastewater can directly enter a water source. A stone and dirt structure can be constructed in the bounds fields near water sources, to divert water flow. The water can be shunted into swales, which are gravel-lined collection ditched that direct the flow of water and promote infiltration. Using these techniques, wastewater can be more effectively contained, and nutrients can be better utilized, ideally reducing the need for chemical fertilizers.

**Potential Challenges and Possible Solutions for Improving Practices in the Zone**

In interviews and focus groups, community members, farmers, and experts explained what they perceived to be the challenges of improving animal waste treatment practices in the Zone, as well as possible ways to “break these barriers.”

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24 EPA. Onsite Wastewater Treatment, 2002.
Lack of Enforcement and Understanding of Government Regulations

One barrier to improvement explained by informants is a lack of proper support or oversight from government agencies. Several informants felt that there is a lack of clarity; so many informants do not understand existing regulations. One farmer explained to us that government agencies rely on coops to distribute information to farmers, yet many producers are not part of these coops. At times is it unclear which government agency is responsible for the oversight of animal farm waste, and several farmers felt as though no agency wants to claim responsibility for governing farm waste practices.

Community informants also conveyed a perceived lack of trust. Several people recounted stories of failed government projects and initiatives, which end up being detrimental to farmers’ livelihood. One striking example was a half-constructed biodigester left on a farmer’s property. The farmer explained that a government program had encouraged and supported this project initially, but never followed through. These governmental blunders damage relations with farmers and make collaboration more difficult.

Current Mindsets and Awareness

As explained by several community informants, the impact of animal waste on the environment is a changing idea in the Zone. An older community member expressed that for decades, farmers believed that there was no need to treat waste, as it was simply a natural fertilizer. Farm animals are considered by many farmers to be a part of the environment and not a contaminant. One expert felt that farmers have been somewhat resistant to changing their animal waste practices, as they do not see a potential for environmental harm.

Farmers and community members frequently spoke to the importance of changing local mindsets in order for farmers to improve their treatment practices. A local expert expressed that for change to occur, farmers must accept that they are contributing to pollution. A chicken farmer in the Zone asserted, “mindset is the first thing we need to change.” He believes that if farmers do not understand their practices have an affect on the environment, then there is no basis for change.

Nevertheless, many farmers did express care for the environment; they have no desire to be contaminating. The difficulty lies in knowing in certain terms how they are affecting the environment. One farmer expressed that she had no way to know if he was contaminating, but if she were to learn that the way she is treating now is contaminating “then I wouldn’t want to ignore the problem.” Many farmers expressed desire to protect the environment and be efficient with waste. Others, who are beginning to understand animal waste can have an effect, still lack knowledge of their exact impact or what changes they might implement. Without a complete understanding of the possible environmental issues, farmers are not in a position to change their treatment practices.
**Economic Difficulties**

Interview participants expressed the importance of the idea that farms are the foundation of livelihood for many families. They are the source of money and food that sustains the family. However, farmers in the Zone often lack financial security. Only some farmers in the Zone have the security and support that membership in a coops offer. Many farmers sell their products to large companies that do not provide contracts or support. Small farmers often experience the constant pressure of competition with larger farms, fluctuating prices, and debt. Farmers explained that implementing a new system would entail spending money with uncertainty of the result. Moreover, farmers explained, they are very involved in day-to-day work running the farms, and therefore have no time to investigate new ways to treat waste. The lack money, time and labor, are major barriers for farmers who might wish to be more environmentally friendly, but lack the means to change their practices.

**Providing Economic Incentives**

Economic incentives were considered by many to be the most important step in encouraging farmers to improve their practices. A local expert said that in his experience, “farmers need an economic incentive. Most people, you have to talk money to be able to open the door.” The economic incentives of changing treatment practices can include: the production of biogas or organic fertilizer, reduced labor or water costs, and protection from fines.

Importantly, community members mentioned that the use of environmentally friendly practices can give farms increased access to tourism revenue. Tourists in search of eco-tourism may be interested in the tours, hotels, and adventure services farms can offer. They also may be more interested in buying food that has been produced in an environmentally friendly manner. Several informants explained that if farmers wish to be members of the global market, they must consider international desires. A milk farmer asserted, “the market is demanding products that have been produced with the environment and animal quality in mind, so this is creating a change”. By promoting the benefits of new environmentally friendly technology, farmers are encouraged to make the change.

**Using Community Examples to “Sell” Economic Benefits.**

Existing community examples demonstrate the effectiveness of new technologies, which has a major influence in the Zone. Several informants spoke to the power of such community examples. Five out of the six farmers interviewed spoke of how their neighbor’s treatment methods influenced their own practices. Systems they might wish to have and their impressions of different technologies, are guided by what they have seen around them. One farmer spoke of how new technologies have a “chain effect”. When neighbors see the effectiveness of his bio-digester they are influenced to change their treatment practices as well. A community expert
explained that “when farmers who have received incentive, share the idea with other people, the idea spreads naturally.”

The Need for Support
Community members often felt that economic assistance was a key factor for the implementation of a new treatment system, especially given the lack of financial security many farmers experience. Several farmers reported that they had either received help creating their system, or would need help with future improvements. Technical assistance and education are critical for the implementation and maintenance of a new system. Without well-informed help, farmers feel that their projects will likely fail. Most informants expressed how pivotal the role of academic institutions and NGOs can be in providing financial, technical, and educational support to farmers. Organizations initiate change, help implement new technologies, educate farmers, and help with the financial barriers.

Maintaining the change: Farmer Investment
In order to maintain change put in motion, many people expressed the necessity for community and farmer project ownership. An expert mentioned that it was key for farmers to have a physical (i.e. digging foundations for a new system) and financial stake in projects. The act of taking ownership and creating an investment plants the seeds for success. One farmer explained that he was expected to dig the hole for a bio-digester that an organization helped him implement at his farm. It was also his responsibility to create a fence and a roof for the digester. By having the support of a local organization in concert with personal investment in the project, the endeavor is more often successful.

Limitations and Future Directions
This study should be considered preliminary work based on limited resources. The research conducted was limited to the rainy season of Monte Verde, and therefore does not represent the full scope of climatic diversity found in the region. It is possible that important differences exist in social or economic practices during other times of the year. The study also reflects interactions with a limited number of farmers, and the scope of agricultural producers may not be fully reflected.

This study was conceptualized as preliminary from its origin, and a major aim of the research is informing the work that will be done in future years as part of the USF Community and Community Health Field School. Areas of interest for future work are detailed below.

Implementation Case Studies
In this study several technologies have been discussed, both in their technical specifications as well as how they fit into existing social dynamics in the Zone. These
data could be used as the basis for implementation case studies, in which technologies could be designed and implemented with community partners. This would provide a valuable opportunity to continue to explore how engineering and anthropology can inform each other for pragmatic applications. It would also stand true to the goals of community based research; the application of knowledge production to tangible benefit as specified by community members. If performed in the context of substantial community interest, the facilitation of technological development in the Zone would give local partners a model for further development, as well as new data about technological and social aspects of implementing change.

Other Aspects of Waste Management

Although animal waste management has proven to be a topic of substantial interest to community members, our results suggest that it is not seen as the most significant contaminator of the local environment. Our data indicate that grey water and solid trash represent more substantial ecological polluters than animal waste for many individuals in the Zone. Therefore, further investigation of these issues with a focus on current perceptions, socio-economic dynamics and technological solutions, could be of interest to the community.

Acknowledgments

Our student research team would like to thank the National Science Foundation, the University of South Florida, and the Monteverde Institute for support. We want to thank our advisors, Dr. Nancy Romero-Daza, Dr. David Himmelgreen and Dr. Serena Ergas, for all their excellent guidance. We would also like to thank our graduate assistants Ali Cantor, Stephanie Paredes and Adib Amini for helping us as colleagues as friends. We also want to express our great appreciation to Gaudy Picado, Jenny Peña, Randy Picado, and all the MVI staff. A special thank you to Luis Carazo, our community advisor.

Biography

Jillian Flavin is an Environmental Science, Technology and Policy student at California State University, Monterey Bay. She is in her Senior year and hopes to work with Monterey’s Environmental Health Department before attending UC Berkeley’s School of Public Health and furthering her education in the field of environmental and public health.
Jordan Atnip is a sophomore honors student at Boise State University studying Civil Engineering and Spanish. After she graduates, she is planning on obtaining her Master’s degree in environmental engineering and joining the Peace Corps.

Elana Curry is a sophomore honors student at Ohio State University majoring in Public Health and minoring in Spanish and Statistics. After graduation, she hopes to attend medical school and pursue a Master of Public Health.

Radhe Patel is a junior at Columbia University. She studies chemical engineering and political science, and hopes to pursue further education in public health and public administration. She aspires to lead new initiatives introducing engineering to international economic development platforms.

Joe Friedman is a senior studying medical anthropology and pre-medical sciences at the University of Vermont. He is minoring in Spanish and biochemistry, and aspires to attend medical school. His future career goals involve combining methodologies of medical anthropology with a medical career.

Thomas Decker is an undergraduate environmental engineering student at the SUNY College of Environmental Science and Forestry in Syracuse, New York. Thomas has been involved in development engineering projects in Honduras, Mexico, Peru, and Costa Rica, and hopes to continue pursuing education in international development and environmental engineering.
References


Appendix I – survey from San Luis

Iniciales del entrevistador ______ Código del Participante: ______
Fecha: _________________ Lugar: _________________

Estamos interesados en saber las diferentes maneras de manejar residuos de animales en las fincas de la zona. Nos gustaría hacerle unas preguntas para saber sus opiniones y experiencias sobre el tema.

Demografía:
Que edad tiene? ____ Cual es su fecha de nacimiento? __________
Género: (Interviewer, mark as appropriate) Hombre ____ Mujer ____
Cual es su ocupación actual? _________________
En que pueblo vive? _________________
Cuánto tiempo lleva viviendo ahí? ________

1). ¿Le voy a leer una lista de cosas, por favor digame, que tanto cree usted que cada una de estas cosas contamina a los ríos en la zona.

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<thead>
<tr>
<th>Cosa</th>
<th>Mucho</th>
<th>Algo</th>
<th>Poco</th>
<th>Nada</th>
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<tbody>
<tr>
<td>Turismo</td>
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<tr>
<td>Animales finqueros</td>
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<td>Fábricas</td>
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<tr>
<td>Desechos (aguas grises) de casas (como por ejemplo de la cocina, del lavado de ropa)</td>
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<td>Desechos (aguas negras) de casas (de los servicios)</td>
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<td>Basura de casas</td>
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<td>Otro:</td>
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</table>

2). ¿Tiene animales para la producción o de trabajo? (Si la respuesta es no, siga a la pregunta numero 6)

Sí ___
No ___

3). ¿Que tipo de animales tiene usted? Dígame todos los que tenga.
   _ _ Cerdos       Cuantos?   ___
   _ _ Vacas       Cuantos?   ___
   _ _ Pollos      Cuantos?   ___
   _ _ Cabras      Cuantos?   ___
   _ _ Caballos    Cuantos?   ___
   _ _ Otro__________
   _ _ Otro__________

4). ¿Que hace usted con los residuos de los animales? Dígame todos los que apliquen
   _ _ Los usa para Compost/abono orgánico
   _ _ Los pone en un tanque de retención
   _ _ Los tira en el campo
5). Le voy a leer otras maneras de manejar desechos de animales. Por favor digame cuales de ellas piensa usted que le gustaría hacer en su casa (Interviewer read ONLY the ones the respondent does NOT already use)
__ Usarlos para Compost/abono orgánico
__ Ponerlos en un tanque de retención
__ Tirarlos en el campo
__ Tirarlos en el jardín/la huerta
__ Usarlos en un Biodigestor
__ Tirarlos en lagunas sépticas

Para cada uno de los que escogió, por favor explique las ventajas que tendría ese método de manejo de desechos.

Para los que no escogió, por qué no?

6). ¿Tenía usted animales de agricultura en su casa cuando era niño/niña?
Sí __
No ___
a). ¿Qué tipo de animales tenía?
__ Cerdos Cuantos? ___
__ Vacas Cuantos? ___
__ Pollos Cuantos? ___
__ Cabras Cuantos? ___
__ Caballos Cuantos? ___
__ Otro_________________
__ Otro_________________

b) ¿Qué hacían en su casa con los residuos de los animales? Dígame todos los que apliquen
__ Los usaban para Compost/abono orgánico
__ Los ponían en un tanque de retención
__ Los tiraban en el campo
__ Los tiraban en el jardín/la huerta
__ Lo usaban en un Biodigestor
__ Lo tiraban en lagunas sépticas
__ Otro (especifique) _______

c) ¿Por qué ha cambiado(o no ha cambiado) las maneras actuales de manejar los residuos de animales en comparación con las de su juventud?
7). ¿Quién se beneficia de los animales para la producción y el trabajo en la zona? (first free list, then sort)

<table>
<thead>
<tr>
<th>Persona/Cosa</th>
<th>Mucho</th>
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8). ¿Cómo afectan a la comunidad los animales para la producción y el trabajo en la zona?

9). Que tanto cree Usted que los animales de las fincas afecten el medio ambiente?
   __ Mucho
   __ Algo
   __ Poco
   __ Nada
   Por qué?

10). Que tan de acuerdo esta usted con la siguiente frase: “las fincas de animales son buenas para una comunidad”
    __ 1) Muy de acuerdo
    __ 2) De acuerdo
    __ 3) Neutral
    __ 4) En desacuerdo
    __ 5) Muy en desacuerdo

   ¿Por qué piensa eso?

Gracias por su ayuda, hay alguna otra cosa que quisiera agregar sobre lo que hemos hablado?
Appendix II – survey from Santa Elena

Iniciales del entrevistador ________ Código del Participante: ______
Fecha: ______________ Lugar: _______________

Somos un grupo de estudiantes del Instituto Monteverde. Estamos interesados en saber las diferentes maneras de manejar residuos de animales en las fincas de la zona. Nos gustaría hacerle unas preguntas para saber sus opiniones y experiencias sobre el tema.

Demografía:
Que edad tiene? ____ Cual es su fecha de nacimiento? __________
Género: (Interviewer, mark as appropriate) Hombre ____ Mujer ____
Cual es su ocupación actual? ________________
En que pueblo vive? ________________
Cuánto tiempo lleva viviendo ahí? ______

1) ¿Le voy a leer una lista de cosas, por favor digame, que tanto cree usted que cada una de estas cosas contamina a los ríos en la zona.

<table>
<thead>
<tr>
<th>Cosa</th>
<th>Mucho</th>
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<tbody>
<tr>
<td>Turismo</td>
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<tr>
<td>Animales finqueros</td>
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<tr>
<td>Abono químico</td>
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<td>Fábricas</td>
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<td>Desechos (aguas grises) de casas (como por ejemplo de la cocina, del lavado de ropa)</td>
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<tr>
<td>Desechos (aguas negras) de casas (de los servicios)</td>
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<tr>
<td>Basura de casas inorgánicos</td>
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<tr>
<td>Basura de casas orgánicos</td>
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<tr>
<td>Otro:</td>
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</table>

2) ¿Ha tenido o ha trabajado con animales para la producción o de trabajo en los últimos diez años? (Si la respuesta es no, siga a la pregunta numero 6)

Sí, ha tenido animales ____
Sí, ha trabajado con animales____
No ____

3) ¿Qué tipo de animales tiene o ha tenido usted?
___ Cerdos Cuantos? ____
___ Vacas Cuantos? ____
___ Pollos Cuantos? ____
___ Cabras Cuantos? ____
___ Caballos Cuantos? ____
___ Otro____________
___ Otro____________
4). ¿Qué hace usted con los residuos de los animales? Dígale todos los que apliquen
___ Los usa para Compost/abono orgánico
___ Los pone en un tanque de retención
___ Los tira en el campo
___ Los tira en el jardín/la huerta
___ Los usa en un Biodigestor
___ Los tira en lagunas sépticas
___ Otro (especifique) ________

5). ¿Hay otras maneras de manejar desechos de animales que le gustaría probar? (don't list options, check off if they say)
___ Usarlos para Compost/abono orgánico
___ Ponerlos en un tanque de retención
___ Tirarlos en el campo
___ Tirarlos en el jardín/la huerta
___ Usarlos en un Biodigestor
___ Tirarlos en lagunas sépticas
___ Otro (especifique) ________

¿Porque?

7). ¡Le voy a leer una lista de cosas, por favor dígame, que tanto cree usted que cada una de estas cosas se beneficia de los animales para la producción y el trabajo en la zona?

<table>
<thead>
<tr>
<th>Persona/Cosa</th>
<th>Mucho</th>
<th>Algo</th>
<th>Poco</th>
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<tbody>
<tr>
<td>Las familias</td>
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<tr>
<td>La comunidad, todos</td>
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<tr>
<td>Los supermercados, vendedores</td>
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<td></td>
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<tr>
<td>Los agricultores, finqueros</td>
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<tr>
<td>Los consumidores</td>
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<tr>
<td>Las empresas, fabricas</td>
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<tr>
<td>Los restaurantes, hoteles</td>
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<td>Otro:</td>
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</table>

8). ¿Cómo afectan a la comunidad los animales para la producción y el trabajo en la zona?

9). Que tanto cree Usted que los animales de las fincas afecten el medio ambiente?
___ Mucho
___ Algo
___ Poco
___ Nada

Por qué?
10). Que tan de acuerdo esta usted con la siguiente frase: “las fincas de animales son buenas para una comunidad”
   ___ 1) Muy de acuerdo
   ___ 2) De acuerdo
   ___ 3) Neutral
   ___ 4) En desacuerdo
   ___ 5) Muy en desacuerdo

¿Por qué piensa eso?

11). ¿Cuáles son los impactos positivos y negativos de los chincheros en la zona?

Positivo:

Negativo:

12). ¿Quiere darnos su información de contacto para hablar mas de este tema?

Nombre: ________________________________________________________________
Teléfono: _______________________________________________________________
Correo electrónico: ______________________________________________________

Gracias por su ayuda, hay alguna otra cosa que quisiera agregar o preguntar?
Appendix III - Theoretical Design for Generalized Farm

Cost
Costs for the ABR were estimated using literature produced by the Centre of Science and Environment of India (CSE) regarding similar systems. In addition to the costs of the reactor shown below, an equilibrium tank estimate would need to be attained from a contractor. Table X shows the cost of two systems; the first of which represents a reactor with a volume of 7.5 m$^3$ and the second with a volume of 2.5 m$^3$. The table demonstrates how reducing water can save money when implementing a treatment system, a barrier that is faced by the small farms of the Monte Verde Zone.

<table>
<thead>
<tr>
<th>Table X: Costs of an Anaerobic Baffle Reactor</th>
<th>ABR with current water usage</th>
<th>R with reduced water usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installation Cost</td>
<td>$1982</td>
<td>$661</td>
</tr>
<tr>
<td>Construction Cost</td>
<td>$2542</td>
<td>$1271</td>
</tr>
<tr>
<td>Total Installation and Construction Cost</td>
<td>$4524</td>
<td>$1932</td>
</tr>
<tr>
<td>Annual Operation Cost</td>
<td>$50-$85</td>
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</table>
Appendix IV – UASB reactor

The system works by utilizing the energy of gravity in an upright tank. The influent, or waste from the source, enters at the bottom of the tank and rises through a “sludge blanket”. The sludge blanket is made up of granules that take up to three months to develop and continually settle with gravity over time. The granules provide a medium for bacteria to survive that in turn decompose the harmful bacteria in the applied waste. The process of granule development can be accelerated by applying activated sludge from a neighboring reactor. Once the waste moves through the sludge blanket decomposition and release of biogas is nearing completion. At this point, an integral part of the reactor called the gas liquid and solid separator (GLSS) divides each component into its respective location (Xiaoqi Zhang Chapter 5 Anaerobic processes).

With respect to the GLSS, the separation of the different states of the waste is important. In the UASB system the HRT or hydraulic residence time is between 4 to 12 hours. This means that the liquid waste can be treated to certain standards within 4 to 12 hours. However, the SRT or solid residence time is much more significant being around 30 days. Therefore keeping separate the different states of matter is essential in the functioning of the reactor. These decomposition times have been proven in practice in many countries, namely Brazil and Columbia who share a geographic similarity with Costa Rica (Sustainable Treatment and Reuse of Municipal Wastewater: For Decision Makers and Practicing Engineers).

The deliverables of the UASB system would be a greater decomposed waste that when applied to pastures had a lower impact in terms of environmental harm and would have more available nitrogen for plant life to take advantage of. The UASB system also produces biogas that can be piped to the nearby worker’s home and would provide initiative for them to maintain upkeep on the system.

What makes the UASB a secondary option to the ABR is the required maintenance to remove built up sludge and because of the GLSS. The GLSS is a commercial product and would be difficult to build or find in Costa Rica. Both of these reasons decreases the economic benefit to farmers in the Zone and has a lesser influence on removing the present social barriers.

Appendix V

Use of Whey


**Treatment of Whey**


