

STRATEGIC ADOPTION AND IMPLEMENTATION FOR BIOGAS SYSTEMS: A
PILOT STUDY IN SAN LUIS, COSTA RICA

by

RACHEL DURHAM

(Under the Direction of Jon Calabria)

ABSTRACT

Limited information is available on biogas digesters in rural agricultural communities of Costa Rica. This study was conducted to analyze the adoption of biogas digesters in San Luis, Puntarenas using semi-structured interviews to produce a weighted overlay analysis that reflected local knowledge of how to best plan for and implement pollution control measures in the future. Semi-structured interviews were conducted with twelve biodigester owners. Content analysis was performed on the interviews using thematic coding, which revealed the strong local concern for nonpoint source pollution caused by agricultural runoff. The results from the themes influenced a weighted overlay analysis, which was performed on the region to identify areas most vulnerable to nonpoint source pollution, revealing that 35% of the study area was highly vulnerable. The results from the semi-structured interviews revealed community support for the existing biodigesters despite widespread installation and maintenance issues. The method of including local opinions into the analysis produced results that can be feasibly adopted by the community and replicated in future geospatial analysis and act as a decision-support tool for those interested in promoting similar projects in this area.

INDEX WORDS: BIOGAS TECHNOLOGY, ADULT EDUCATION,
WATERSHED ASSESSMENT, WEIGHTED OVERLAY ANALYSIS

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DEDICATION

This thesis is dedicated to Alvaro Vega Anchía, a UGA Costa Rica staff member,
neighbor, biogas enthusiast, and friend.

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CHAPTER 1

INTRODUCTION

My interest for biogas began in 2012 when I saw a digester under construction at a rural public school in Kenya to provide electricity and cooking gas for children. Throughout my graduate career in planning, my focus has always been in waste management, striving to reuse what is already there. With biogas in particular, I am particularly interested in the cultural acceptance of these systems in developing countries. This led my research to understanding behavioral drivers and attitudes, estimating loads, and siting future digesters to foster increased implementation for the systems in rural areas.

Anaerobic digesters, commonly referred to as biogas digesters, are systems that capture gases produced from decaying organic matter in a controlled, oxygen free environment. Gas comprised primarily of methane can be burned as a natural gas energy source, similar to propane. The most common utilizations of the gas are to fuel a gas stovetop or power electricity. Though they are infrequently integrated throughout the United States, biogas systems have been in existence for hundreds of years and are used around the world in both developed and developing countries (Marchaim 1992, Council 2016).

Biogas systems vary in size and output quantity and quality (Cheng et al. 2014). The most advanced digesters produce methane that is then converted to compressed

natural gas, which can be used to fuel engines (De Carvalho 1985). Other systems, like those examined in this study, can be simpler with the gas traveling from the digester through a single pipe to be burned on a stovetop. In the United States, most of these systems are built at wastewater treatment facilities, factory farms, or landfills (Federation 2015, 2016b, 2016c). The high methane production rate from the vast amount of organic waste in these areas increase their potential as successful sites for biogas systems.

Advantages and Disadvantages of Biodigesters

Biogas digesters have a huge potential in developing countries. Not only do they provide a gas that can be used for energy or cooking, they incentivize management of agricultural waste, which promotes a number of environmental benefits. By allotting all animal waste into a biodigester, less is carried via runoff to surface water and less methane is released into the atmosphere. Disadvantages of the system can include the cost and lack of required maintenance knowledge.

Studies show that people in developing countries are skipping the beginning steps of industrial development and going straight to the most efficient contemporary forms of technology and infrastructure (Chmiel and Bhattacharyya 2015, Mainali and Silveira 2013). Many communities in rural areas are beginning their transition to electricity by running mostly on alternative energies (Buran et al. 2003). Generally speaking, rural agricultural communities in developing countries face strong pressure on the issues of energy access, resource depletion, and climate change mitigation (Rakotojaona 2013). Energy access is often linked to social issues, and rural communities that depend on traditional solid fuels tend to face more difficulties, such as health problems as a result of

smoke and fewer educational opportunities due to the time required to collect biomass, such as firewood (Programme 2000). Women and children are affected by these educational and health obstructions more than men, as the roles of collecting firewood and water are most often left to them in traditional communities (Alemayehu 2015). Biogas digesters are socially impactful in these areas, providing the means to cook without requiring the time consuming duties of finding firewood.

In addition to social benefits, biogas digesters provide economic benefits to rural communities. By purchasing the materials and labor locally, the cost of the systems is going into the local economy. Because of the simplicity of some systems, digesters can be constructed using local materials in areas with very limited resources. In areas where the biogas is used to fuel a gas stove, the digesters also save recipients money by eliminating the cost or lowering the amount of purchased natural gas needed for cooking (Feng et al. 2009). The slurry from the output of biodigesters is nitrogen and phosphorus rich and can be used on crops, reducing the cost of purchasing fertilizer (Surendra et al. 2014, Kinyua, Rowse, and Ergas 2016).

Environmental benefits include improving water quality by the reduction of both nonpoint source and point source pollution to water sources from bordering farmlands. Nonpoint source pollution is defined as indirect contamination, such as animal waste from husbandry farms entering a water source via stormwater runoff. Point source pollution is direct contamination, such as waste from a stable. Biodigesters assist in the reduction of agricultural pollution by incentivizing the organization of waste from roaming livestock and barns.

As atmospheric temperatures slowly and steadily rise, global leaders are beginning to focus on reducing the amount of carbon emissions into the atmosphere, searching for particular ways to mitigate the anthropogenic sources of greenhouse gases (IPCC 2014). One benefit to using biogas digesters is the reduction of methane entering the earth's atmosphere. Agricultural livestock produce 30% of methane in the atmosphere (Saborío Viquez 2013). Methane (CH_4) is 21 times more concentrated than carbon dioxide, making it a substantially more potent greenhouse gas that takes far longer to break down (Scholtz et al. 2014). Greenhouse gases are those that, when released into the atmosphere, capture radiation emitting from the earth. This warming of the atmosphere in turn warms the earth, thus affecting the global climate. Since methane remains in the atmosphere for longer than most, it contributes to the overall greenhouse gas effect and has the potential to significantly warm the earth. After methane is captured by a biogas system, it is stored for burning. Following this combustion process, it is released into the atmosphere as carbon dioxide (CO_2), a less concentrated gas that will stay in the atmosphere for a shorter amount of time, making less harmful than methane. The use of biogas digesters at a large scale can significantly reduce the amount of methane reaching the earth's atmosphere. Deforestation is another major contributor to climate change and is particularly high in developing countries that use firewood for cooking (Kinyua, Rowse, and Ergas 2016). Biogas digesters replace the need for firewood, decreasing the amount of deforestation.

The major disadvantage to biogas digester is that they require capital costs. Maintenance materials to construct a digester are often available but too expensive or difficult to transport. While they could be easily utilized in rural regions, often times

these areas are difficult and costly to reach with needed supplies (Torretta et al. 2012). More sophisticated designs can create more gas, but require knowledge of maintenance and operation. Methane is highly flammable and incorrect installation or use could present a dangerous fire hazard. Tubular designs using plastic bags are susceptible to holes and damage from too much sunlight.

Research Objective

This thesis will examine the implementation of biogas digesters to augment propane gas in the town of San Luis in Puntarenas, Costa Rica. My primary research question is: In what ways can biogas digester systems be more efficiently planned for those living in San Luis, Puntarenas? Sub questions and objectives include: assess vulnerability to nonpoint source pollution; what can be learned from the attitudes and behaviors of participants and how can those responses be applied to future projects; identify strengths and weaknesses of the existing projects and plan so future projects could be implemented with the highest probability of success.

Thirteen biodigesters were constructed on private farms with no written follow-up accounts on their success. The methodology is a multidisciplinary approach, using both semi-structured interviews and weighted overlay analysis. Semi-structured interviews with twelve of the thirteen digester recipients provided insight on the motivations that lead the owners to participate in the project. Lessons learned by understanding the attitudes and behavior of participants aided in future recommendations for projects. Respondent data included total amount of biogas produced and financial savings on the purchase of cooking gas each month. Responses from the interviews

guided criteria in the Geographic Information Systems (GIS) vulnerability assessment to determine areas highly susceptible to nonpoint source pollution.

Limitations and Delimitations

There were many limitations to the study, primarily because of limited resources and access to data. Three months were spent at the study area, limiting the time to complete field work. Delimitations were set to make the study as applicable as possible in this area to promote future research and biogas implementation.

Limitations of GIS Analysis

While GIS analysis and ArcSWAT, the Soil and Water Assessment tool, are extremely powerful and efficient tools, data was limited. The elevation data used in the weighted overlay was limited by its 30m cell size, and could have created a more precise results had it been a higher resolution. ArcSWAT was used only for watershed delineation. The hydrology data excluded all tributaries. Using a DEM with a larger extent would have given the entire basin but was not necessary for this study, which focused on surface water Floodplain and springhead data would provide further data on areas vulnerable to nonpoint source pollution. Rainfall data was not available in the study. Soil data was not available at a specific enough level for this analysis. Without textural classification (loamy, sandy, etc.), runoff predictions based on the watershed delineation were limited.

Limitations of Interviews

The nature of semi-structured interviews allows the respondent to give unprompted information, giving the participant an opportunity to expand on answers and

provide additional insight. However, this method does not give each respondent the opportunity to discuss the same subjects and has the potential to provide slightly ambiguous results. Two translators were used during the interviews to convert Spanish to English. This study only used the primary researcher to for data interpretation and thematic coding of the interviews.

Delimitations

The study area chosen for the weighted overlay consisted of the Monteverde and Guacimal districts within the Puntarenas province, selected because the town of San Luis is contained within these two districts. Siting for future digesters to avoid point source pollution is not discussed in this study due to lack of GIS data. Though the drainage network would be more detailed with tributaries included, the data available in the study gives sets an example of how to identify areas highly vulnerable to nonpoint source pollution.

CHAPTER 2

LITERATURE REVIEW

Implementing new ideas and technology into a community takes time and strategic planning. In this study, a hybrid approach melds content analysis, GIS suitability, and the diffusion of innovation theory to create a plan for biodigesters in San Luis and the surrounding region. The goal was to learn about the existing projects from the owners themselves. In doing so, knowledge of attitudes towards biodigesters could be understood, leading to a deeper understanding of the value of the projects in the community and how to best plan them for the future.

In addition to local opinion, foundational research texts provide context for research. This literature review evaluates the concepts and application of thematic coding, the diffusion of innovation theory, and a weighted overlay analysis using GIS technology, discussing these three processes in detail before delving into how they were used in this particular study. Qualitative evaluations may be conducted in a variety of ways. The diffusion of innovation theory has long been used to analyze the success or failure of new technologies in a community. Weighted overlay provides tangible results that can be visually understood and quantifiably verified, providing an accessible output of information. Understanding the foundational literature on these concepts is key to understanding how they can be connected into one research goal.

Environmental History of Costa Rica

As global temperatures continue to rise, world leaders are shifting focus to reduce anthropogenic causes of greenhouse gases (IPCC 2014, Saborío Víquez 2013). A significant portion of these human-induced emissions are caused from animal husbandry. Global methane emissions from manure have nearly doubled in the last forty years, emphasizing the need for waste mitigation in the agricultural sector (IPCC 2014). There is great opportunity within Costa Rica for the reduction of agricultural methane emissions.

In the late 20th century, Costa Rica experienced detrimental impacts on its natural environment. From its time of settlement to the 1970's, the government heavily encouraged the clearing of land for the agriculture industry, resulting in a 41% loss of forest cover (Bower 2014). Following political stability in the late 1980's, eco-tourism became an economic driver of Costa Rica, capitalizing on its biodiversity and natural beauty to attract tourists from all over the world (Granoff et al. 2015).

Legislation was introduced to protect the remaining forests and incentivize afforestation in critical conservation areas (Granoff et al. 2015). In addition to benefitting from natural ecosystem services provided by vegetation, the heavy emphasis on the need for environmental protection has provided a strong ecotourism industry and creates a “promising development strategy” that will continue to benefit the country (Koens, Dieperink, and Miranda 2009). While some legislation has been put into effect in recent years, the 1946 Water Law remains the primary legal reference for water resource management, despite its critiques of being outdated for the current population and needs (Albuquerque 2009, Bower 2014). Promotion of ecotourism in a way that “conserves the

environment and improves the welfare of local people” encouraged positive outcomes from the visitors and host community, providing employment opportunities for nationals and natural attractions for tourists (Hunt et al. 2015). These efforts have proven successful, with World Energy ranking Costa Rica second in 2013 for environmental sustainability (Council 2013).

While it serves a beneficial example to other countries eager to reduce their carbon footprint, Costa Rica has areas that need improvement with regard to environmental sustainability. Two of the greatest areas needing enhancement are greenhouse gas emissions and wastewater management (Granoff et al. 2015). Costa Rica has relatively low emissions compared to other countries with similar populations, incentivizing alternative energies such as hydraulic and geothermal energies, which provide 67% and 15%, respectively, of the country’s energy needs (Molina 2014). However, national greenhouse gas emissions are rising, primarily from the transport sector and an increase in privately owned vehicles as opposed to the traditional use of public transportation (Granoff et al. 2015).

Water resource management and allocation of wastewater remains a large opportunity for improvement for sustainability in Costa Rica. Of the 34 stream basins identified in Costa Rica, only 16 have been analyzed for plans to manage a balance of demand and water availability and a need remains to address the allocation of wastewater (Bower 2014). Biogas digesters can address the issues of wastewater mitigation and greenhouse reduction in Costa Rica by reducing constituents in existing wastewater and reducing the amount of methane being released from agricultural livestock (Lansing et al. 2010).

Costa Rica has established 37 corridors throughout the country as a strategy for implementing conservation approaches at a regional level (SINAC 2009). The study area for this investigation is located within the Bellbird Biological Corridor (Corredor Biológico Pájaro Campana or CBPC), which includes individuals and representatives of institutions in the area from the Monteverde Cloud Forest Reserve to the Puntarenas coast who are committed to the protection of natural resources and promoting environmental initiatives in the area. CBPC includes representatives from the Conservationist Association of Monteverde, the Tropical Science Center, the Costa Rican Conservation Foundation, the Institute Association Monteverde, the University of Georgia- Costa Rica, Cloud Forest Reserve Santa Elena, and Conservation Area Arenal-Tempisque (Campana 2016). By using stakeholder input and actions to conserve biological connectivity, they preserve the community and restore natural resources. The vision of the CBPC is to create “a region with high eco-systemic integrity where the communities that inhabit it thrive and preserve the environment using to the appropriate uses of natural resources” (Campana 2016). In their most recent strategic plan, CBPC lists the production of renewable energy as a major opportunity for the region, promoting the advancement of biogas systems in the region.

Beginning in 2003, Programa Biogás UEN-CENPE, a program within the national electricity company Instituto Costarricense de Electricidad, installed biodigesters throughout the country, ranging from small bladder systems like those in this study, in rural areas to giant lagoon digesters in large commercial farms (Hernández 2014). In 2015, Programa Biogás identified potential of 34 MW that could be created from biogas, with only 6% currently installed. Of those 6%, only 5% of the biodigesters are located in

the Puntarenas province, which includes the study area. Table 2.1 identifies the location of the biodigesters within the country.

Table 2.1. The location of existing biodigesters recorded in a 2015 study by Programa Biogás. (Hernández 2014)

Province	Share of Biodigesters
Limón	6%
Alajuela	43%
Guanacaste	5%
Puntarenas	5%
Cartago	19%
Heredia	7%
San José	15%

The promotion of environmental sustainability throughout Costa Rica and the Bellbird Biological Corridor has increased greatly over the past few decades and will continue to remain a high priority in this region. The potential for biogas to replace propane in this area is great.

Biogas in San Luis

In 2011, the University of Georgia Costa Rica (UGACR) constructed their first biodigester, a tubular plug-flow digester to treat swine waste (Lansing et al. 2010, Camacho 2015). After its successful installation and source for a cooking fuel, this digester became a model for the area. Then, UGACR held informational meetings with community members about the benefits of biodigesters and selected 13 community members within the town to cost share an implementation. The donor provided the materials for the digester (around \$2,500 USD) and the recipient was responsible for labor and maintenance, such as digging the trench and constructing a protective shelter to

block sunlight and fence out to resist animals from puncturing the polyethylene bladder (Camacho 2015). These systems were a collaborative effort, providing a gas cooking source for recipients and educational opportunities for visiting students and tourists.

The biogas digesters in the study area the tubular type, in which waste flows through a shut off valve into a polyethylene bag, where it breaks down and releases the biogas, which comes out through a pipe above the bag (Surendra et al. 2014). A filter at the entry value blocks entry of large chunks of organic waste, which would take longer to break down and could create blockages, from entering the bladder. This filter requires daily cleaning, which normally takes less than 10 minutes. Effluent then flows down another pipe and is released as nitrogen rich water and dispersed into pasture. This design was chosen because of its simplicity and cost efficiency. One of the digesters in the study had an extra bag for storage, similar to the digester in Figure 2.1, but the rest had only one bag that held both the waste and gas. Data in Table 2.2 shows theoretical yield measurements for the biodigester on the UGACR campus, which was used as a model for the thirteen in the study.



Figure 2.1: View of one of the UGA Costa Rica biodigesters, which served as a model for the thirteen digesters in San Luis.

Table 2.2. Specifications and Potential Yield from Tubular Biodigester (UGACR 2012, Kinyua, Rowse, and Ergas 2016)

Bag Volume	15.39 meters ³
Potential Biogas Yield/ Day	0.35 meters ³ per pig
Percent Methane	60%
Heat Energy Production Rate	0.62- 1.6 MJ/animal per day
Potential Methane Combusted per month	0.11 tonnes (metric ton)

The digesters are constructed and sited into the landscape with attention to elevation. Methane is lighter than air and will naturally flow upwards, so they are sited below the elevation of the house with a pipe connecting the bag straight to the house. Biogas digesters require a consistently warm temperature to produce gas, between 15–30°C (Kinyua, Rowse, and Ergas 2016). The year-round consistent warm temperature allows for the bladder system to be built without additional warming buffers to the environment (2016a). The bags are placed in a 2 m deep trench for additional warmth and protection. A protective shelter is built around the digesters lined with mesh, locally called *serán*, to protect it from animals and UV radiation, which degrades the polyethylene over time. Understanding the specifics and capabilities of the technology, the next research focus is how it can be applied and accepted by its host community.

Content Analysis

A large portion of this study dealt with qualitative data obtained from semi-structured interviews. Qualitative research is investigated in a strategic, unbiased way to explore the understanding of such data, performing analyses that can be easily replicated in future research. A longstanding approach to examining qualitative documents is content analysis. In its traditional definition, content analysis is a “research technique for making replicable and valid inferences from data to their context” (Krippendorff 1980). Through a framework that is conceptual, analytical, and methodological, data with no previously specified groupings can be transformed into categories for further analyzation. The primary goal of content analysis is to make a clearly specified inference which is justified by the open, knowledge-based research. Hypotheses are tested in the process,

usually statistically. Krippendorff stresses that replication is the most vital factor and the researcher's methodology should be able to apply to a completely different dataset and still function (Krippendorff 1980). Following this model, Figure 2.2 illustrates the seven steps to complete content analysis.

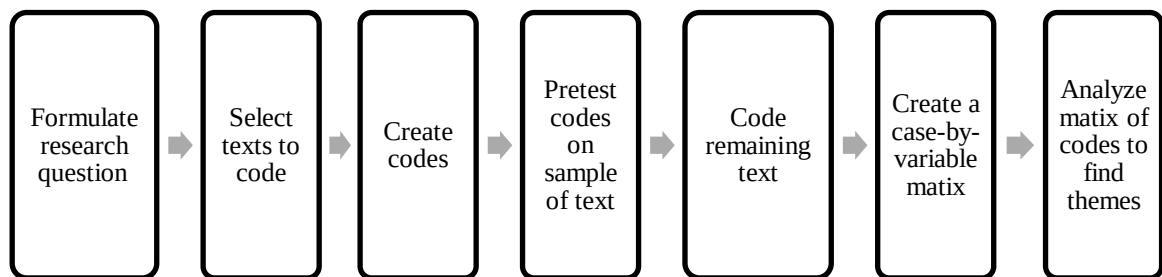


Figure 2.2. Seven Steps of Content Analysis Adapted from Bernard (2013)

Patton defines going into the field as “the evaluator gets close to the people under study through physical proximity for a period of time as well as through development of closeness in the social sense of shared experience and confidentiality... [making] possible description and understanding of both externally observational behaviors and internal states.” (1990). Semi-structured interviews have a framework of questions but allow for participants to expound upon any topic they choose, allowing both topics of interest and unforeseen topics to be included in the interview (Galletta 2013). Similar studies have used semi-structured interview process to gauge environmental motivators in Costa Rica (Newcomer 2005).

Qualitative research analysis is equivocal, and “the challenge is to make sense of massive amounts of data, reduce the volume of information, identify significant patterns, and construct a framework for communicating the essence of what the data reveal... there

are no absolute rules except to do the very best with your full intellect to fairly represent the data and communicate what the data reveal given the purpose of the study” (Patton 1990).

Given this challenge of massive amounts of data, thematic coding is a technique often used in content analysis. The researcher examines the text in question and creates a “code,” one specific idea that is tagged. Boyatzis defines thematic analysis as a way of seeing, stressing that “observation precedes understanding” (Boyatzis 1998). The author goes on to describe the three phases as 1) recognizing the “codable moment” 2) deciding it fits into your code and 3) interpreting the meaning of that code. The process of studying the document is repeated, developing many codes throughout the entire text. After careful analysis, trends in the codes, or “themes”, are found in the phenomena, from which conclusions are made at the final stage of analysis.

Having a detailed codebook aids in the transparency and replicability of the project. MacQueen et al. gives an example of a codebook entry that contains a code, brief definition, expanded definition, specific times to use and not use the code, and examples of the code in the text (MacQueen et al. 1998). Codebooks of this type are included in research in which texts are analyzed by several coders unfamiliar with the data, which was not applicable in this study. A 1987 study examined what men and women look for in a partner (Hirschman 1987). In her study, Hirschman created a data table for her codes, arranged in a “case-by-variable matrix” for analysis. By creating a chart that showed the quantity of code tags for each individual, she could analyze the frequencies of codes per participant. In a similar study, “first-order categories” were developed to produce broad codes (Kurasaki 1997). Upon continuous rereading of the data, she created “second-

order” subcategories within her original codes. This became her “codebook” on which she based her research.

Multi-Criteria Evaluation

Geographic information systems and remote sensing gives researchers the opportunity to use technology as a tool to perform analyses using geospatial data (Bagdanavičiūtė and Valiūnas 2013). In 1969, McHarg revolutionized the approach to understanding the impact human design has on nature (McHarg and Mumford 1969). He stressed that the environmental suitability of a site be considered before any action occur, using overlays to examine criteria. Multi-criteria evaluation (MCE) is a technique that applies several criteria to a dataset to examine the vulnerabilities and opportunities based on evaluation criteria (Voogd 1983, Carver 1991). The purpose is to optimize sites for intersection.

Multi-criteria evaluation can be incorporated into GIS functions. MCE theory does not include specific ways to process data, such as how to determine the weight of specific criteria, putting the responsibility on the researcher to set up an appropriate model. In a study using MCE to determine landfill siting, researchers used Weighted Linear Combination and Analytical Network Process modelling to determine the weights of their variables (Motlagh and Sayadi 2015). Priority bias is that which explains the different weighting options that result in various end results. Carver concludes that GIS is useful for multi-criteria evaluation as it provides a spatial framework, capable of less random and unbiased results (1991).

Following the multi-criteria evaluation method, weighted overlay combines inputs of multiple variables into one composite raster file. Each data layer is reclassified into a set range of integers, based on the suitability scale chosen by the researcher. Weighted overlay combines the reclassified data using the common integers.

Researchers incorporate MCE into their land suitability analysis to allocate pollution sources in eastern Lithuania (Bagdanavičiūtė and Valiūnas 2013). Using a variety of socio-economic and environmental factors, the authors identified parcels of land suitable for allocating polluters. The weights applied to each sub-criteria were determined using the Analytical Hierarchy Process (Saaty 1980).

Diffusion of Innovation Theory

The use of biodigesters in San Luis was evaluated using the diffusion of innovation theory and examined the spread of the technology throughout the community. Rogers coins and discusses the diffusion of innovation theory that explains the phenomena occurring as an idea or technology is adapted by a community it is not in (Rogers 1983). Diffusion is “the process by which an innovation is communicated through certain channels over time among members of a social system” (1983) It has been widely analyzed and discussed in regards to the types of innovations that can be reviewed, statistics about the rate of adoption, and factors that can, generally speaking, influence the innovation and lead to its success or failure.

The four main factors in the diffusion process are the innovation, channels of communication, time, and social system. Rodgers defines the innovation as “an idea, practice, or object that is perceived as new by an individual or other unit of adoption”

(1983). The characteristics of innovations vary greatly and control the rate of a successful adoption or a failure. The innovation itself is not necessarily new, but is new to the target group.

Communication channels describe the means by which the idea is spread throughout a community or group (Rogers 1983). Studies have shown successful diffusion is more likely to occur when communication happens between peers (Van Slyke et al. 2007, Goldsmith and Goldsmith 2011). For example, a study of mothers with newborns showed they were far more likely to use the internet to validate health issues than ask a friend or look to mass media (Sundstrom 2016). Using these results, social workers could focus on introducing their ideas on this type of media to reach new mothers with limited access to healthcare. Communication on a face-to-face level as an interpersonal channel (Rogers 1983). Rogers makes the generalization that “interpersonal diffusion networks are mostly homophilous,” meaning networks that are primarily communicated on a face-to-face level are conducted between those of similar backgrounds (Rogers 1983). Stronger networks occur between people of similar circumstances and demographics (Padel 2001, Sundstrom 2016).

The innovation-decision process is the time it takes for the idea to get from its first introduction to its adoption or rejection. “Adoption” of an innovation is the point at which the innovation is accepted and is considered the best choice by its target community (Rogers 1983). The rate of adoption by a community depends on a variety of factors, as shown by those listed in Figure 2.1. Rogers notes that “in general, innovations that are perceived by receivers as having greater relative advantage, compatibility, trialability, observability, and less complexity will be adopted more rapidly than other

innovations” (1983). While some variables cannot be controlled in the process, others can be manipulated to encourage adoption. For example, the norms of the social system could not be changed or controlled to promote the use of biodigesters. However, the biodigester recipients could be required to show future potential participants a demonstration of their existing systems, increasing the observability of the projects and the rate of their adoption.

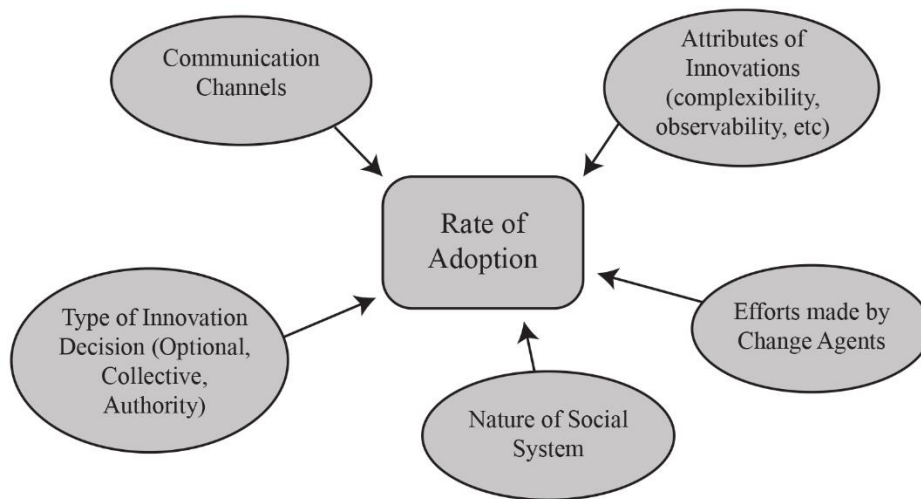


Figure 2.3: Adopted Summary of Variables Defining the Innovation’s Rate of Adoption (Rogers 1983)

The diffusion of innovation theory suggests five categories depending on when the community adopts the new idea, as shown in Figure 2.4. The process begins with the innovators. The innovators are those who discover a problem, perceive it as such, and act upon it. They “set the stage”, studying and analyzing the new idea and providing a platform for which they begin the spread of it (Robertson 1967). In this study, the UGA Costa Rica campus would be considered the innovators. With the installation of the two

original biodigesters on campus, they created the model that would be replicated throughout the town. They possessed many of the characteristics Rogers explains for innovators, such as “venturesomeness” to try a new idea and the financial resources to absorb any loss that could occur if the project failed (Rogers 1983). They held meetings with potential participants, sharing information about the project and using one of their own biodigesters as an example. These actions of developing relationships and networks within the community is a vital role of the innovators. The categorization is sometimes criticized for taking into account the characteristics of the adopters rather than the differing circumstances that occur in reality (Bishop, Shumway, and Wandschneider 2010).

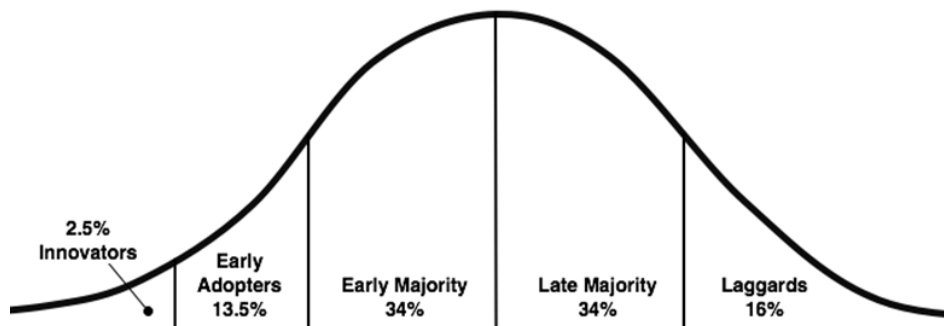


Figure 2.4: Adopter Categorization Based on Innovativeness (Rogers 1983)

The early adopters follow next, bringing the innovation deeper into the community. Early adopters are generally more integrated into the local system, providing a familiar link to the new innovation (Padel 2001). Early adopters typically have more of an opinion leadership and influence the perception of the project by the community.

One study suggests targeting groups other than the innovators for initial spread of innovation (Bishop, Shumway, and Wandschneider 2010). When looking at the

implementation of anaerobic digesters on US dairy farms, they used a dual-motive theoretical model and found that the economic incentives and found that few were seeking profit as an end goal. Motivation by environmental stewardship was actually higher, leading to believe that the encouragement of environmental motivators could be further investigated in this study. Taking this review of foundational literature into account, a hybrid research approach helped examine the best implementation methods for biodigesters in San Luis. A GIS analysis for vulnerability to nonpoint source pollution was a result based on answers from a semi-structured interview. Applying the diffusion of innovation theory provides a foundation to suggest best practices for successful implementation.

CHAPTER 3

METHODOLOGY

This study sought to answer the research question- In what ways can biogas digester systems be more efficiently planned for those living the San Luis, Puntarenas- using a hybrid approach that used results from a qualitative analysis to then frame a GIS spatial analysis. Results from this study can be distributed throughout the community, providing context for future planning. The thematic coding provided frequencies of themes found within the text of the semi-structured interviews, giving insight to values and motivations for the project from the perspective of the participant. The interviews also provided feedback on the existing projects, including the output of a working digester and economic benefits. Based on the respondent responses during the interview, a weighted overlay analysis was developed. The weighted overlay analysis provided areas at high risk of nonpoint source pollution, which could be used in future study. Following the framework of the diffusion of innovation theory, adoption strategies can be made to market the projects to potential future participants. Based on these findings, recommendations for future biodigester recipients and locations can be planned.

The methodology for this study is a hybrid approach, using semi-structured interview as a basis to inform the pragmatic demands for the weighted overlay analysis. This multi-pronged method sought to answer the research question in a way that would

factor in local opinions. Figure 3.1 shows an overview of the steps taken to achieve the adoption recommendations, later discussed in Chapter 4.

Once local geospatial data had been obtained, information from the semi-structured interviews was used as a basis for the weighted overlay analysis and for the weighting of individual variables in the weighted overlay. This technique is unique in that it can be replicated in areas with little or no access to GIS, providing a platform for the community to obtain information with which it would otherwise not have access.

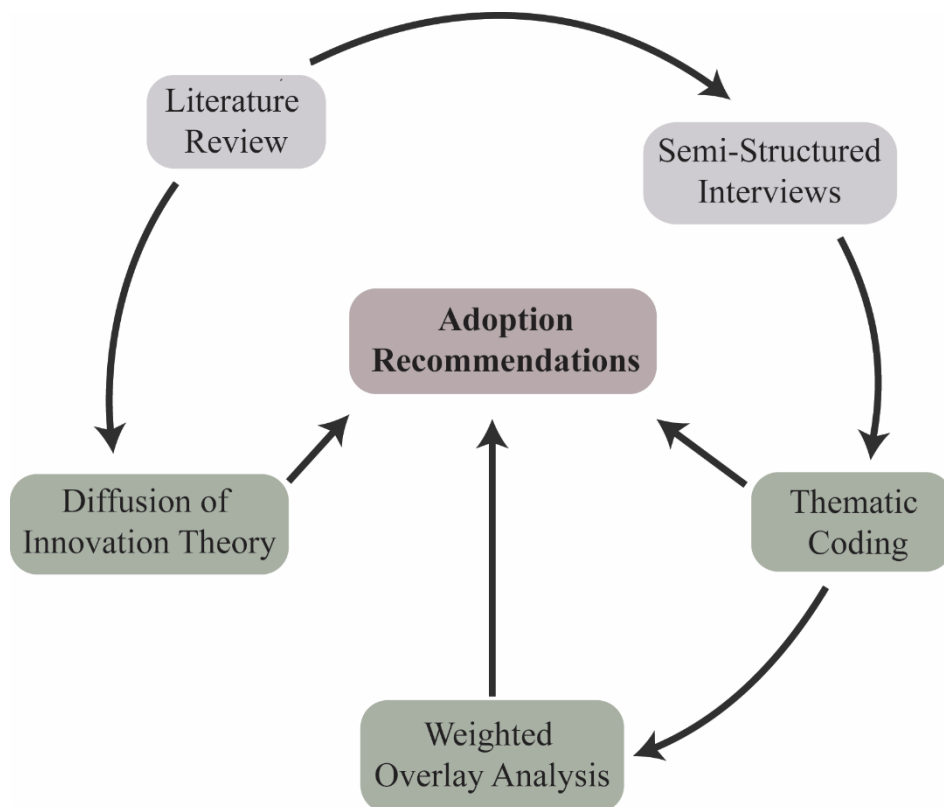


Figure 3.1 General Overview of Research Methodology

Semi-Structured Interview

A semi-structured interview allows reciprocity between the interviewer and respondents, as well as maximize the amount of information shared about the project. The interview followed Galletta's general semi-structured protocol- beginning with broad, comfortable questions, following with more specific questions, and concluding with any additional points the participant wished to say (2013). Following IRB protocol, respondents were allowed to skip any question if wanted.

Following this protocol, the study was conducted in a way to minimize researcher bias. I lived in the town of San Luis for two months prior to the interviews, spending time getting to know the language, culture, and people. While still an outsider, time and care was taken to approach the interviews from an informed standpoint.

A survey, adopted from Newcomer (2005), containing 60 questions was presented to each participant, taking roughly 30 minutes to an hour to complete. In its semi-structured format, participants were allowed to expound upon any subject. The interview included demographic information, motivations for participating in the biodigester project, current status of biodigester, and financial savings while the digester was in use. The answers were recorded by the translator on paper and later transcribed into a digital file. The method used in this investigation was the same as Kurasaki in her study of third-generation Japanese Americans (Kurasaki 1997).

Weighted Overlay for Nonpoint Source Pollution

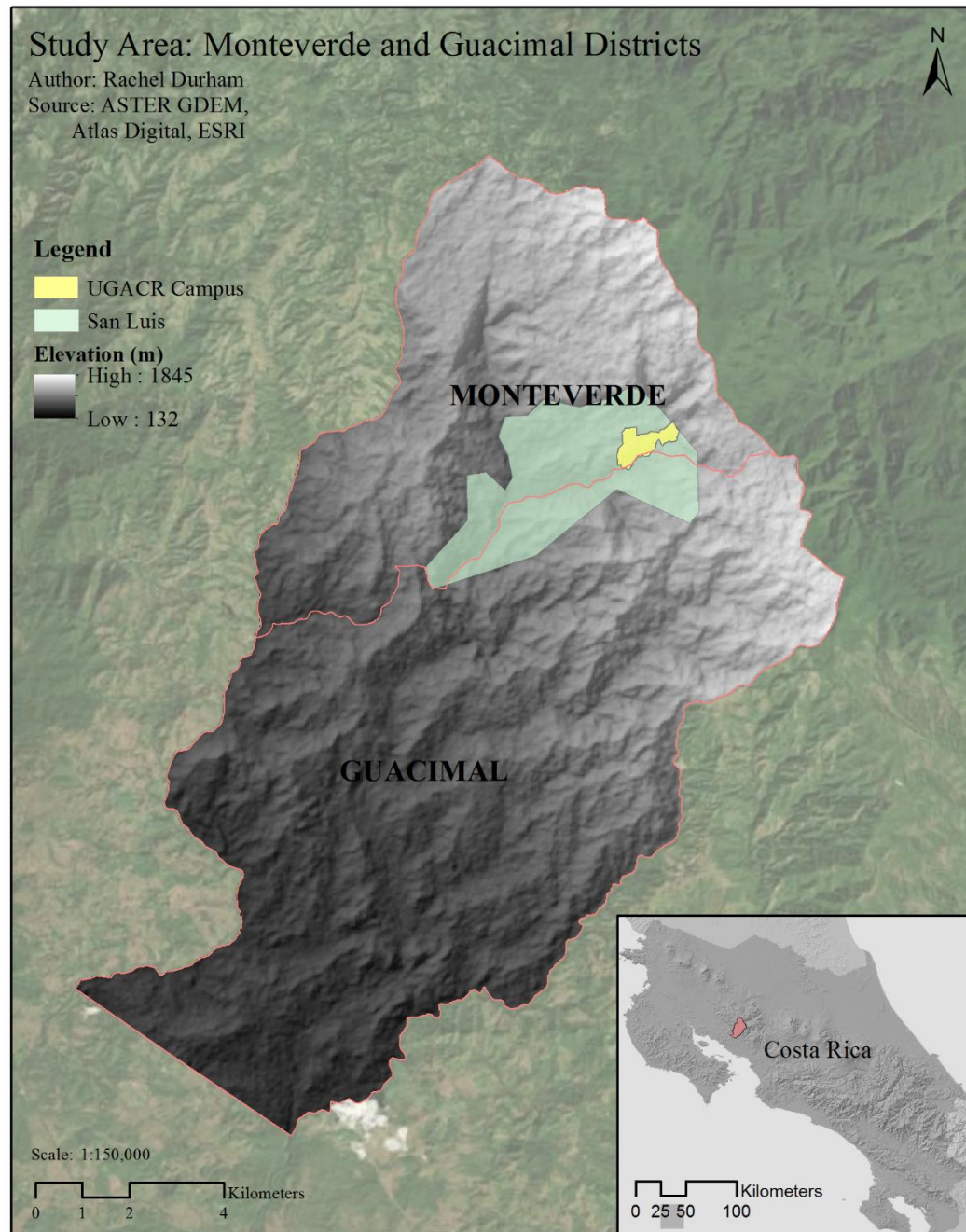


Figure 3.2. Study Area with Hillshade

The study area chosen was a combination of the Monteverde and Guacimal districts in central Costa Rica, projected using Proyección CRTM05. Elevation and

hillshade data was produced using 30m ASTER earth observations. Suitability ranking in this study was determined using a land use suitability analysis based on with environmental criteria, adopted from Bagdanavičiūtė and Valiūnas (2013). The overlay was set to an evaluation scale of 1 to 9 by 1. The study area, shown in Figure 3.2, was analyzed using a suitability score between 0-3 based on the following descriptions:

3= Most Vulnerable (MV): area *most vulnerable* to environmental harm from agricultural pollution or runoff and therefore the *greatest* opportunity for the placement of a biogas digester.

2= Vulnerable (V): area with the mild concern for agricultural pollution; would benefit from a biogas digester.

1= Least Vulnerable (LV): Area *least vulnerable* to environmental harm caused by agricultural runoff; would still benefit from a biodigester.

0= Restricted (R): Land not available for the construction of a biogas digester due to river or vegetation protection laws. Criteria with a suitability score of 0 were entered as “Restricted” in the weighted overlay tool in ArcMap.

Completing a suitability analysis using weighted overlay allows different types of datasets (for example, vegetation and elevation) to be compared and combined into output of similar units. Aspect was considered to have a minimal effect on site suitability and was not included in the study because of the region’s proximity to the equator (Guswa and Rhodes 2009). Weights are assigned to the different datasets, giving some a heavier influence on the outcome of the analysis (Motlagh and Sayadi 2015). Using similar variables in a comparable study, the three criteria used in this study were the

longest drainage pathway, vegetation cover, and slope (Bagdanavičiūtė and Valiūnas 2013). Weights were assigned using the swing weights technique, using frequencies of themes to delineate importance and define the ranking (Fischer 1995).

The swing weights method was used in this study because it allows the analysis to reflect the attitudes and values of the community, giving decision-makers the role of assigning importance to criteria that are being compared (Fischer 1995). The swing weights method asks participants to rate the criteria based on personal importance and then those rates are used to determine the weight of each criteria (Wanishayakorn and Ngorsuraches 2016). In this study, the decision makers were the respondents who completed the surveys and the criteria were the three criteria (slope, existing vegetation, and water protection areas) used in the weighted overlay analysis. This study applied the swing weight technique in a novel way, using the theme frequencies revealed by thematic coding to rate the criteria. The frequencies of the themes were ranked as the highest frequencies were weighted the most.

In her application of the swing weight technique, Malczewski asked her participants to rank three criteria based on what they felt was most important for a particular site suitability analysis (2000). She assigned the criteria the weights of 100, 60, and 30 for price, slope, and views, respectively. Normalizing the weights provided the percentages 53%, 31%, and 61%, respectively, to be used in the weighted overlay analysis for suitability.

Advantages of MCE including the ease of replicability when the process is detailed and documented, better understanding of the objectives for research, and the increase in accountability and structure of the analysis (Voogd 1983). The amount of

control wielded by the researcher can be both an advantage and disadvantage (allowing the objective to be met) but, if used wrongly, can also be manipulated to arrive at a preconceived idea or decision. In this study, the swing weights technique was used to avoid this researcher bias.

Using the subcriteria described in Table 3.1, a weighted overlay analysis was completed on the study area. Cell sizes of 30m were used on all raster datasets. ArcSWAT was used to determine the longest flowpath based on a DEM. Slope was categorized based on slope erodibility potential in a similarly structured suitability study (Bagdanavičiūtė and Valiūnas 2013). The classification used in this study rated criteria using a four class suitability levels, shown in Table 3.1, for the site selection. The levels were least vulnerable, vulnerable, most vulnerable, and restricted with the suitability scores of 1, 2, 3 and 0, respectively.

“Drainage” in this study refers to a combination of river, longest path, and reach data. The drainage dataset was created by the watershed delineator tool in ArcSWAT using a 30m DEM with the river data burned in (Scopel 2012). Costa Rican federal law dictates a mandatory forest protection buffer around rivers that is 15m on flat ($< 2\%$) terrain and 50m on other ($> 2\%$) terrain (Rica). As calculated in the slope analysis, only 2% of the study area contains less than a 2% slope. Due to this minimal amount, the buffers were calculated at 50m for the entire area. Following the law to protect vegetation and soil surrounding rivers, the buffer used in this study was 50m on each side of the pathway. The 50m buffer was placed around the entire drainage network, protecting it with the mandated buffer as if the whole network was an existing river system.

Table 3.1: Weighted Overlay Matrix for the Study Area. Suitability were ranked:
 3= Most Vulnerable (MV): area most vulnerable to environmental harm from agricultural pollution or runoff and therefore the greatest opportunity for the placement of a biogas digester.

2= Vulnerable (V): area with the mild concern for agricultural pollution; would benefit from a biogas digester.

1= Least Vulnerable (LV): Area least vulnerable to environmental harm caused by agricultural runoff; would still benefit from a biogas digester.

0= Restricted (R): Land not available for the construction of a biogas digester due to river or vegetation protection laws. Criteria with a suitability score of 0 were entered as “Restricted” in the weighted overlay tool in ArcMap.

Criteria	Sub-criteria	Description	Attribute	Suitability Class	Suitability Score	Criteria Weights
Slope	Runoff risk into stream	Steep	> 10 % slope	MV	3	25%
		Moderate to steep	5-10 % slope	V	2	
		Gentle to moderate	2-5 % slope	V	2	
		Flat to gentle	1-2 % slope	LV	1	
		Flat	< 1 % slope	LV	1	
Proximity to Drainage Pathways		Hilly Ground (>2% slope)	< 50 m from flow path	R	Restricted	50%
		Hilly Ground (>2% slope)	> 50 m from flow path	MV	3	
Vegetation	Suitable for project	Type of vegetation cover	No forest, Pastureland	MV	3	25%
	Unsuitable for project	Type of vegetation cover	Deciduous Forest, Mature Forest, Secondary Forest, Tree Plantation	R	Restricted	

Metadata Sources

Table 3.2. Metadata Information Sources

Map	Data	Source
Study Area	30m DEM	The DEM used in this study was a combination of three DEM files, provided by Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). ASTER GDEM is a product of Japan's Ministry of Economy, Trade and Industry (METI) and the National Aeronautics and Space Administration (NASA).
	Monteverde and Guacimal Boundary	District data was provided by Atlas Digital 2014.
	Hillshade	The hillshade was created using the "Hillshade" tool with the 30m DEM as the input raster.
	UGA Costa Rica Campus Location	Courtesy of UGA Costa Rica.
	Aerial Imagery	ESRI Online.
Slope Analysis	30m DEM	The DEM used in this study was a combination of three DEM files, provided by Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). ASTER GDEM is a product of Japan's Ministry of Economy, Trade and Industry (METI) and the National Aeronautics and Space Administration (NASA).
	Hillshade	The hillshade was created using the "Hillshade" tool with the 30m DEM as the input raster.
	Slope	The slope was created in ArcGIS using the 30m DEM as an input raster.
	Aerial Imagery	ESRI Online.
Drainage Analysis	30m DEM	The DEM used in this study was a combination of three DEM files, provided by Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER). ASTER GDEM is a product of Japan's Ministry of Economy, Trade and Industry (METI) and the National Aeronautics and Space Administration (NASA).
	Aspect	Aspect data was retrieved from United States Geological Survey.
	River Data	The river data was provided by Atlas Digital 2014. This included both intermittent and permeant rivers.

Map	Data	Source
Drainage Analysis	Longest Path and Reach	The longest path and reach were calculated in ArcMap using the ARCSWAT tool.
	Hillshade	The hillshade was created using the "Hillshade" tool with the 30m DEM as the input raster.
	Aerial Imagery	ESRI Online.
Existing Vegetation	Vegetation Type	The vegetation data was provided by Atlas Digital 2014. The types of vegetation included in this dataset included secondary forest, mature forest, deciduous forest, plantation, pasture, and no vegetation.
	Hillshade	The hillshade was created using the "Hillshade" tool with the 30m DEM as the input raster.
	Aerial Imagery	ESRI Online.
Results	Vulnerability Classifications	Vulnerability was classified using a weighted overlay analysis using drainage pathways (50%), vegetation cover (25%), and slope (25%).
	Hillshade	The hillshade was created using the "Hillshade" tool with the 30m DEM as the input raster.
	Aerial Imagery	ESRI Online.

CHAPTER 4

RESULTS

The results from this study are twofold. First are the themes that emerges from the content analysis, including the identification of community collaboration regarding the biodigester project. A codebook was created to rate the frequencies of coded text, identifying community collaboration, preemptive water protection, and wastewater treatment mitigation as the as the highest themes throughout the interviews. The interviews were also examined using the diffusion of innovation theory, which indicated the respondents could be classified as the “early adopter” phase. Using three criteria identified in the semi-structured interviews, a weighted overlay analysis located most vulnerable sections of the study area to nonpoint source pollution and identified 35% being highly susceptible.

Semi-Structured Interview and Thematic Coding Results

The biodigester recipients (n=12) in San Luis were interviewed during this study. The demographics data showed that that majority of participants were between 35-64 years old, with 50% of the participants between 35-49 years old and 33% between 50-64 years old. 25% have a monthly salary of ¢100,000 – ¢200,000 per month (\$250 - \$500 USD), 60% of participants have a monthly salary of ¢201,000- ¢400,000 (\$501-1000 USD), and 15% have a monthly salary of ¢401,000 – ¢800,000 per month (\$1,001 -

\$2,000 USD). Twelve of the thirteen participants were male. Of these 13 digesters, four are currently fully-functional and nine are not in use. The original two on UGA’s campus are fully functional.

Following the coding method by Kurasaki described in Chapter 3, the data was coded using “First-Order” and “Second-Order” categories. The first-order codes were the main themes, discovered easily in the texts. As the coding process was repeated, these main themes were broken down into more specific themes to provide a deeper analysis. Table 4.1 displays the code book that was developed for this study.

Table 4.1: The codebooks developed for the semi-structured interviews.

First-Order Category	Second-Order Category	Numeric Code
Water Issues	Preemptive protection of water sources	1.1
	Wastewater management and mitigation	1.2
Ecotourism	Promotion of ecotourism on property	2.1
Community Concern	Community collaboration to share information	3.1
	Concern for general public health	3.2
Economic Benefits	Value of cooking gas	4.1
Failures	Operational failures and mechanical issues	5.1
	Failure due to inadequate protective covering/fence	5.2
Knowledge about Digesters	Decrease in smells associated with swine production	6.1
	Advice and recommendations for future digesters	6.2
Environmental Issues	Environmental protection in general	7.1
	Steepness of landscape contributing to nonpoint source pollution	7.2
	Protection of existing forest	7.3

Following the model of Hirschman, a case-by-variable matrix was produced to determine the frequency of themes throughout the interviews (Hirschman 1987). Frequencies of themes, though ordinal, can be compared and analyzed as representations of community attitudes, as listed in Table 4.2. However, it still provides the foundational knowledge of issues that matter to the respondents. The second highest rated concern is Code 1.1, the preemptive protection of water sources. To reflect the concerns of the community, this led to the suitability analysis, which was to determine areas most vulnerable to nonpoint source pollution. Interpersonal communication proved to be an important channel of communication in this study, as the respondents were all neighbors and went to one another for advice or help on the project.

Table 4.2: Frequency Matrix for Coded Interviews

Code	Frequency
Community collaboration to share information	25
Preemptive protection of water sources	24
Wastewater management and mitigation	22
Value of cooking gas	21
Environmental protection in general	17
Advice and recommendations for future digesters	10
Promotion of ecotourism on property	8
Operational failures and mechanical issues	8
Failure due to inadequate protective covering/fence	6
Concern for general public health	5
Decrease in smells associated with swine production	4
Steepness of landscape contributing to nonpoint source pollution	2
Protection of existing forest	2

GIS Results

Based on this ranking and the method determined by Malczewski (2000) in Chapter 2, the weights for the suitability variables were calculated and normalized using the following equations:

$$\text{Drainage Pathways weight} = 100 / (100 + 50 + 50) = 0.50$$

$$\text{Slope weight} = 50 / (100 + 50 + 50) = 0.25$$

$$\text{Vegetation Cover weight} = 50 / (100 + 50 + 50) = 0.25$$

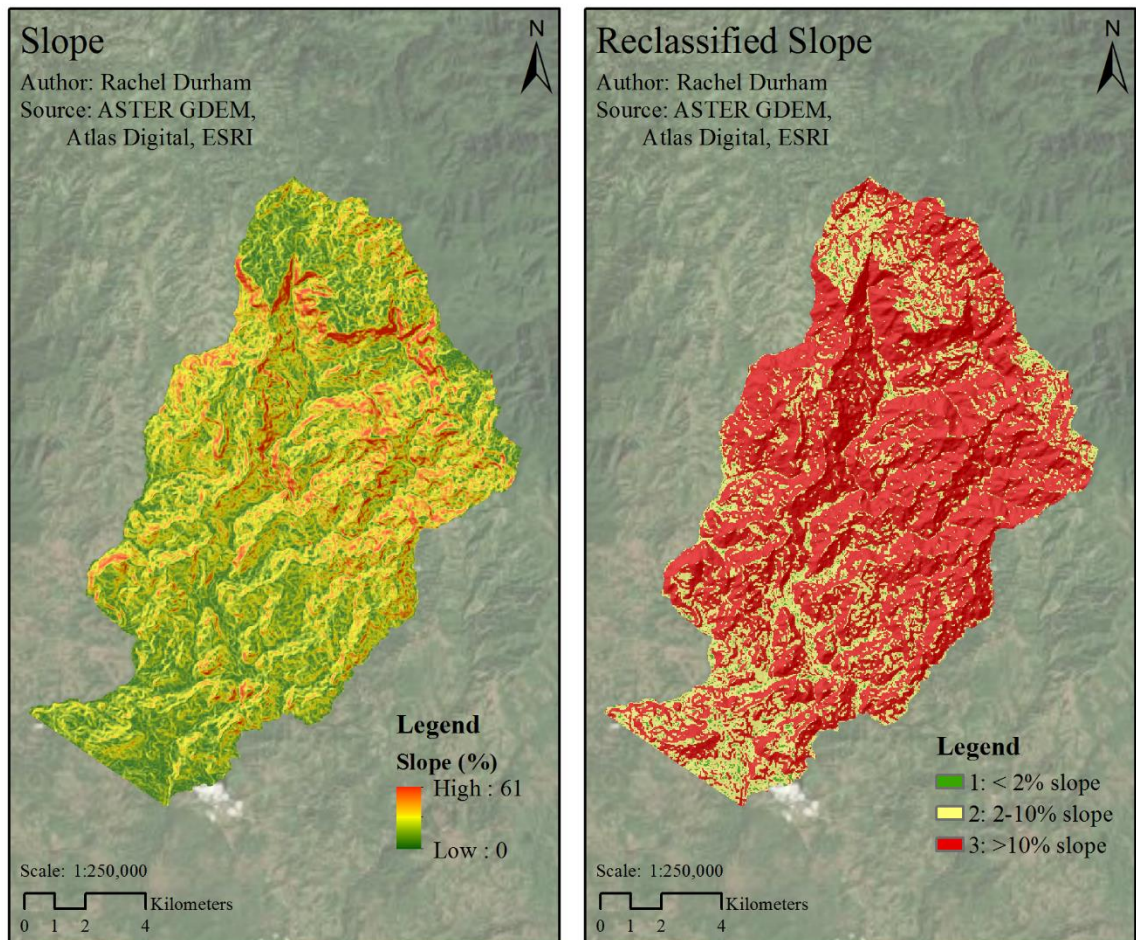


Figure 4.1. (Left) Slope analysis of study area using 30m DEM.

(Right) Reclassification map of slope ranking areas based on vulnerability.

Using the matrix in Table 3.1, the slope was reclassified into three categories: Least vulnerable (2% slope), vulnerable (2-10 % slope) and most vulnerable (> 10% slope) based on methods used in a similar study (Bagdanavičiūtė and Valiūnas 2013). Based on analysis of the semi-structured interviews, water protection was found to be most valued, followed by forest protection and concerns for high slope runoff, which had equal frequencies. The elevation range in this area is great, reaching from 132m (433ft) to 1,845m (6,053ft). The high slope seen near the northern tip of the study boundary is the edge of the Monteverde Cloud Forest Reserve. The highest slope was chosen as most vulnerable because it was the most at risk for runoff caused by nonpoint source pollution. 72% of the area was ranked most vulnerable; 26% vulnerable, and 2% least vulnerable.

The weighted overlay tool reclassified my original raster input values with an evaluation scale of 1 to 9 in increments of 1. The value 9 was selected as the maximum value as it would represent the most extreme result of my data. The only criteria in the analysis with a value of 1 were the areas under 2% grade in the slope analysis. Only 2% of the total area fell into this category, giving very little areas with that slope value. When combined with other values in the weighted overlay tool, these areas overlapped with other criteria, raising their final vulnerability score and removing all vulnerability (1) areas on the final analysis.

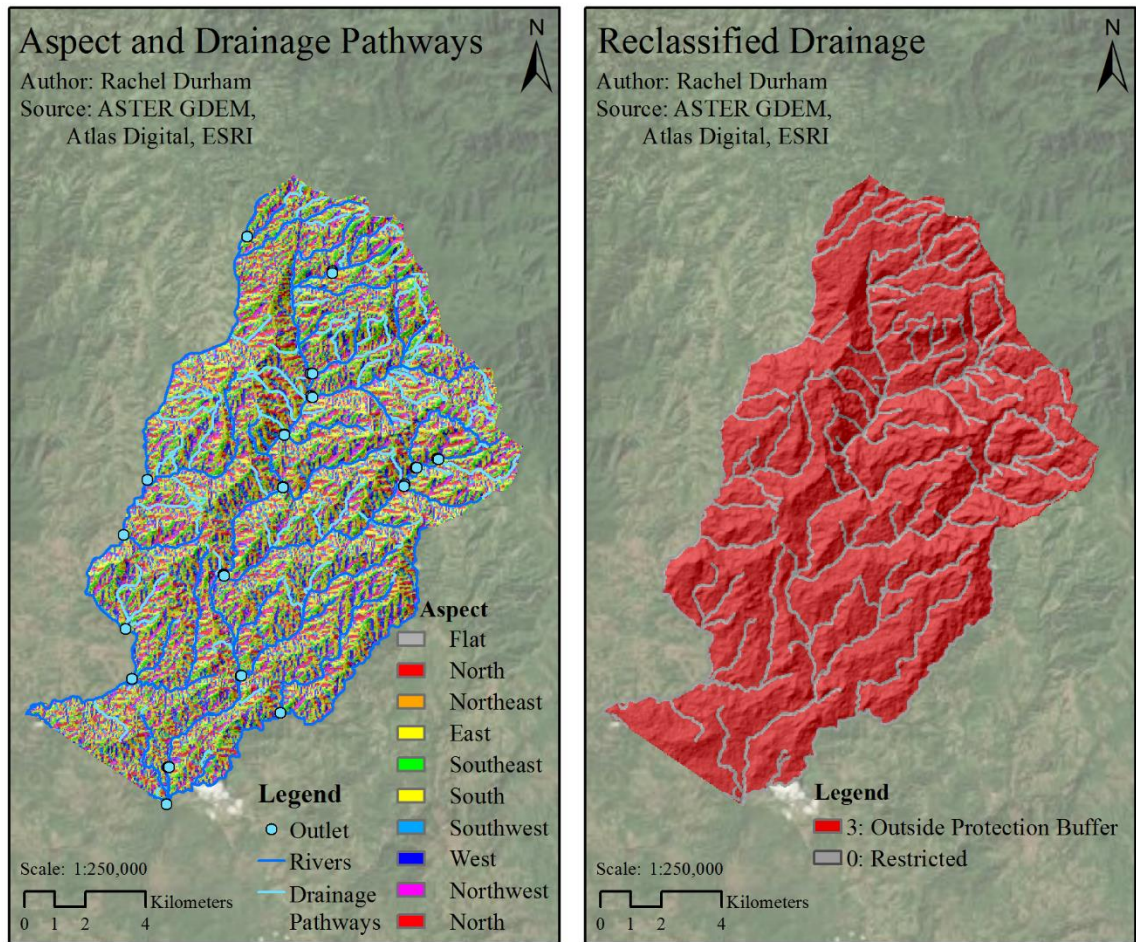


Figure 4.2. (Left) Drainage pathway analysis of the study area. (Right) Reclassification map using a 50m buffer each side of drainage paths.

The drainage pathway analysis was completed using ArcSWAT. The 30m ASTER GDEM was used in the watershed delineation tool within ArcSWAT, locating sub basins, longest path, and reach of runoff within the study area based on elevation. Aspect shown on the left map in Figure 4.2 shows the slope direction. 84% of the study area was not in a protected zone.

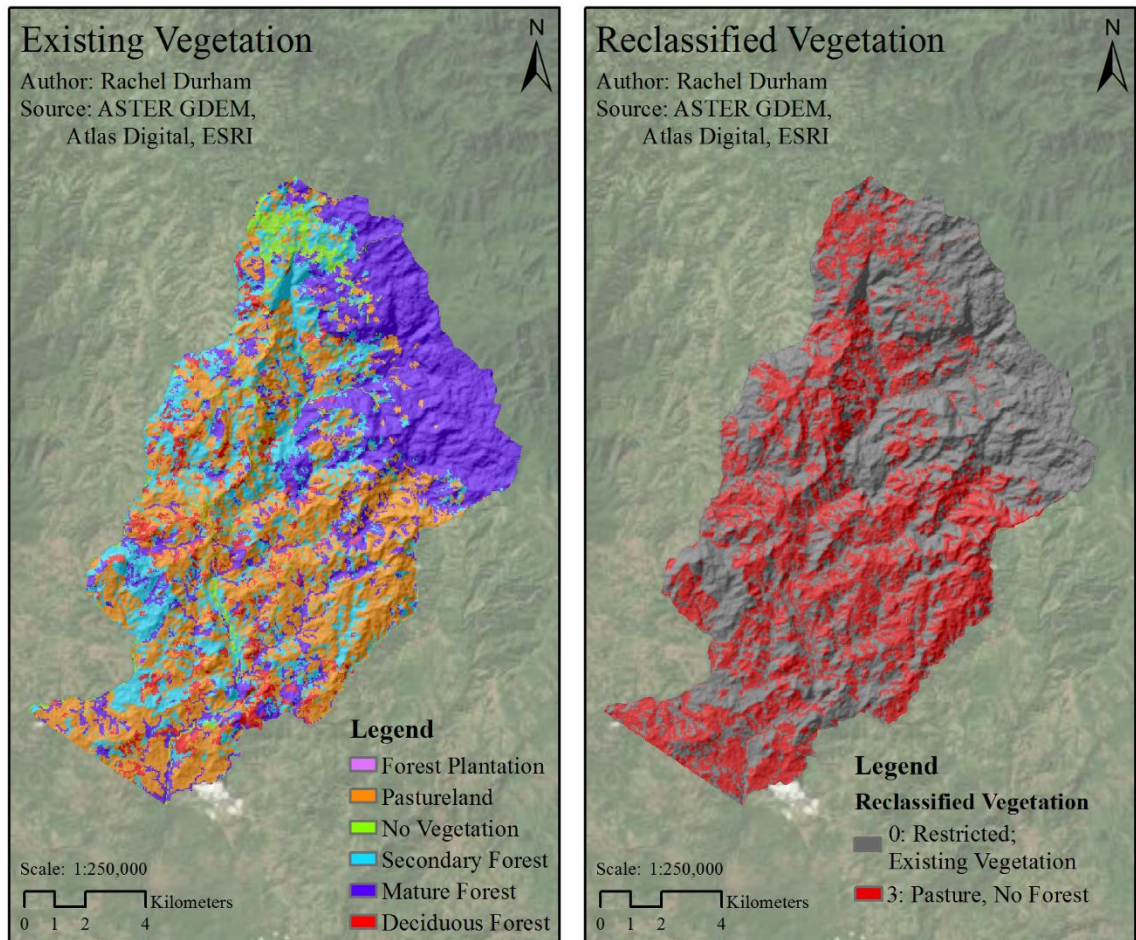


Figure 4.3. (Left) Vegetation analysis representing areas with existing tree cover. (Right) Reclassification map using flow vegetation cover.

The vegetation was split into the six following categories: secondary forest, mature forest, deciduous forest, plantation, pasture, and no vegetation. The region was divided into two categories- covered and uncovered. The covered area was considered restricted in this analysis, as it would require the removal of vegetation, which is illegal. The covered area included secondary forest, mature forest, deciduous forest, and protected forest areas. The uncovered area included pastureland and non-vegetated land. 41% of the study area did not have existing forest cover.

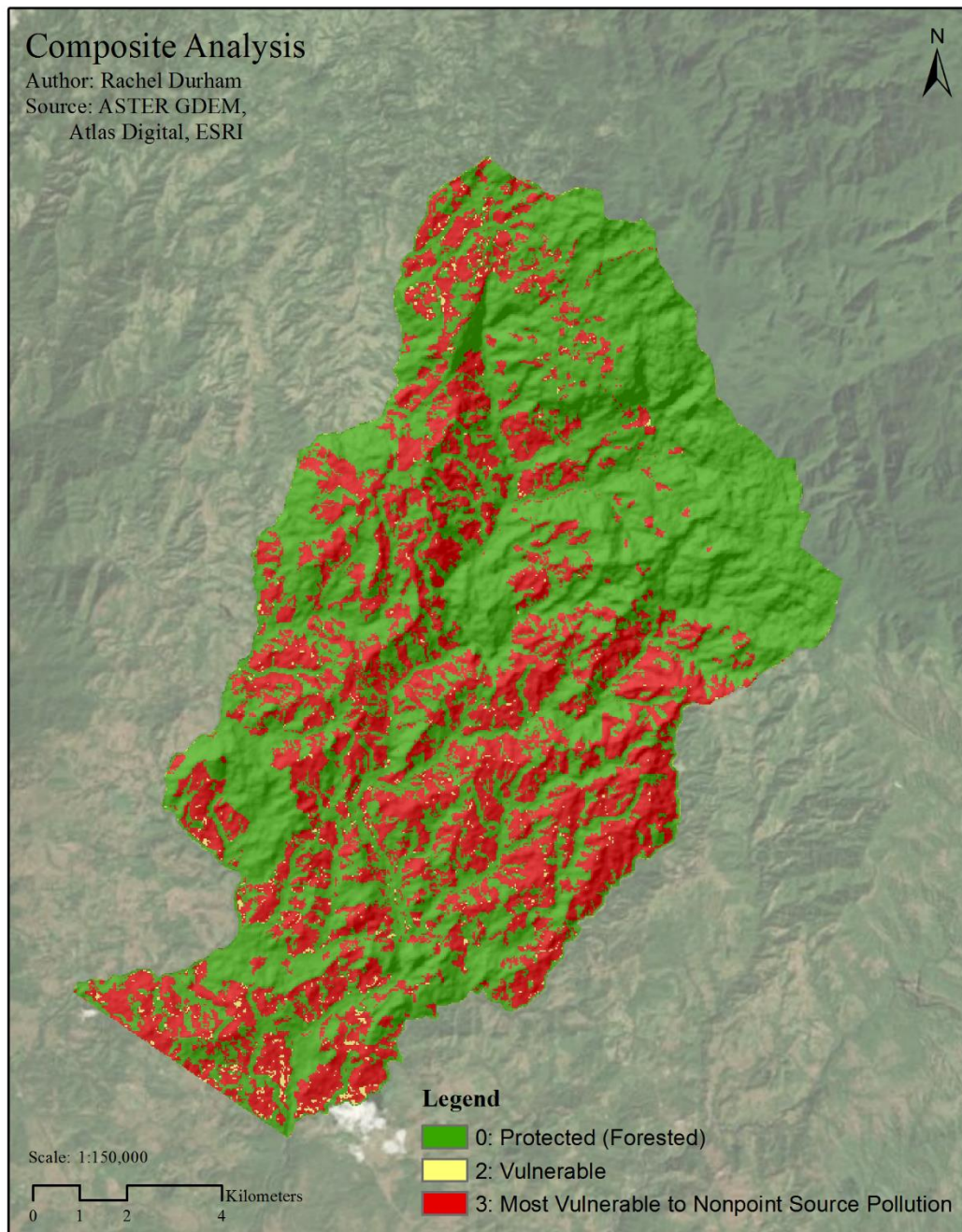


Figure 4.4. Results from the weighted overlay analysis using reclassified drainage, slope, and vegetation.

The reclassification of the criteria allowed for the combination of different units into one common scale of 0-3, shown above, and were combined to produce a composite

map illustrating areas of *highest* vulnerability for nonpoint source pollution due to lack of vegetation, proximity to water sources and high slopes. The red represents areas of unsuitability due to existing vegetation or forest buffered river protection area. Table 4.3 lists the results from the weighted overlay analysis.

Table 4.3. Results from weighted overlay analysis.

Reclassified Value	Description	Area (m²)	Area (km²)	Percent
0	Restricted	106381	106	64%
1	Least Vulnerable	0	0	0%
2	Vulnerable	1527	2	1%
3	Most Vulnerable	59187	59	35%

The purpose of the analysis was to pinpoint areas of high vulnerability for nonpoint source pollution via runoff, with the suggestion that these areas be considered a high priority for nonpoint runoff pollution reduction. 64% of the total study area (see Figure 5.1) was determined to be “restricted” (vulnerability score=0) from the vulnerability analysis. While this area may be vulnerable, it is classified restricted because there are legal barriers or existing vegetation in place that prevent it from being the future site of a biodigester. Recalling the earlier finding that 59% of the land is restricted from construction to protect existing vegetation, the results of the analysis are plausible.

CHAPTER 5

DISCUSSION

An evaluation of results from semi-structured interviews demonstrated a strong sense of community collaboration among the respondents, supporting the diffusion of innovation theory and the importance of interpersonal relationships as a communication channel. The interviews provided helpful information on common maintenance problems, which could be addressed early on with future recipients to avoid confusion. Quantifiable benefits from the biodigesters included cooking time per day using biogas and monthly average savings on propane. These results showed considerable benefits and could be used in future marketing efforts. The GIS analysis revealed roughly one-third of the study area was most vulnerable to nonpoint source pollution.

Thematic Coding and Semi-Structured Interview Findings

The thematic coding results in Table 4.2 displayed expected positive results, such as water protection and value of cooking gas. An unanticipated code was the decrease in smells associated with swine production. While biodigesters incentivize the organized and strategic disposal of waste, it isn't used to reduce smells. Another theme discovered was the lack of ecotourism motivations coded throughout the interviews. Four respondents listed that a portion of their property was dedicated to ecotourism. Ecotourism was tagged throughout the interview eight times, but never as a motivating

factor for requesting a biodigester. One recipient recognized that benefit not long after its installation and began including it in his ecotourism tour. Biodigesters fit perfectly with ecotourism, a benefit that should be heavily marketed to potential recipients.

Community collaboration was the code with the highest frequency in the interviews with 25 different tags, supporting the application of diffusion of innovation theory to this community. The social learning theory is similar to the diffusion of innovation theory, except the ideas are spread through the former via observation, rather than communication (Rogers 1983). In this study, almost all were introduced to biodigester systems through face-to-face communication, which appears to have been effective. When asked how they learned about biodigesters, 11 of the 12 participants listed staff at UGA Costa Rica, the innovators. Rogers defines the early adopter group as the “respectable” leadership within the community that provide an example of the technology to the rest of the community (Rogers 1983). The thirteen biodigester recipients in San Luis would be categorized as early adopters, maintaining Rogers’ characteristics of adopting the new idea while there is still some uncertainty of its success. These digesters for these thirteen participants were installed within a year of one another, creating a sense of comradery between the owners that was often referenced during the semi-structured interviews. The challenge at this phase in the adoption timeline is to shift into the next phase in which the early majority begins adopting the technology.

Much was learned throughout the interviews about general maintenance problems and troubleshooting issues associated with the biodigesters. At the time of the survey, four out of the twelve biodigesters were currently in use. Of the eight biodigesters not in

use, two were never used, one had a bag malfunction, and five were punctured by cows due to a lack of insufficiently constructed protective shelter. When the biodigesters were installed, the donor funding covered the price of the bag and installation costs, leaving the digging of the trench up to the recipient. During the interviews, each protective shelter was different and six of the protective shelters had failed. Some had holes while others had been blown over in the wind.

Based on these results, it is necessary during future projects for technicians to ensure the project is built to specifications including a durable protective cover. Personal communication with the campus manager provided me the rough cost estimate of \$2,100 USD (Camacho 2015). The protective structures are considered agricultural infrastructure and therefore do not require construction permits, so certain materials could be substituted to cut back costs. Many of the shelters followed the Earth University model, but the interviews revealed that the wind is much stronger in San Luis than the Limón province, where Earth University model is located, which has led to the serán ripping in many of the shelters. The bladder style biodigester on the UGA Costa Rica campus had a protective shelter that is in perfect condition and should be replicated for future projects. Recipients with functional protective shelters should be visited by the follow up crew to learn how they protect against the wind and animals. Another cost share option could be to reimburse recipients after a follow-up inspection to ensure proper follow-up care.

Of the ten biodigesters that were at one point in use, no quantification of their benefits had been recorded. From a broad standpoint, the functioning digester counts as a success. There is no way to have a functioning digester without at least some of the benefits, such as cleaner water, gas production, waste management. All of the functioning

digesters were credited with cleaning wastewater, but only two of the recipients had their water actually tested before and after the digester. This seemed to make a stronger impact on the owners. Taking water samples for each of the recipients once or twice per year would strengthen the credibility of the campus and the projects. The average monthly cost of propane was 16.500 colones (\$31 USD) and the average savings with the use of the biogas digester was 8.690 colones (\$16 USD). On average, the recipients used the stoves to cook for 2-3 hours per day.

All of the participants used a gas stove for cooking before the installation of the biodigesters, so the switch from propane to biogas was a small change. The fact that the residents in the area already cook and gas stoves lessens the “complexibility” of the project, an attribute affecting the rate of adoption (Rogers 1983). Reports containing these statistics and benefits could aid in promoting future adoption of biogas in the community.

GIS Discussion

35% of the study area was found to be highly vulnerable to nonpoint source pollution based on slope, proximity to identified surface water drainage areas, and existing vegetation protected by national legislation,. The primary explanation for this is the existing forest, which covered 59% of the study area. Steep slopes exist throughout both of the study districts, as depicted by the hillshade in Figure 4.1. Elevation played a large part in the evolution of biodigesters in San Luis, as many noted in the semi-structured interviews that agricultural runoff was polluting their surface water. While the suitability analysis in this study only tested for vulnerability to nonpoint source pollution, slope steepness could also be used as a suitable factor in future studies that test for site suitability. The polyethylene digesters in this study are passive and must be constructed at a lower elevation than the stove they fuel.

Runoff occurring in the flow path is more susceptible to reach surface water and should therefore be avoided for construction of biodigesters. The lack of tributary data limited the results as it left out a significant number of smaller pathways. The long flow path provided the main pathways taken by drainage. Without knowing the complete drainage network, areas vulnerable to nonpoint source pollution were not identified on the map.

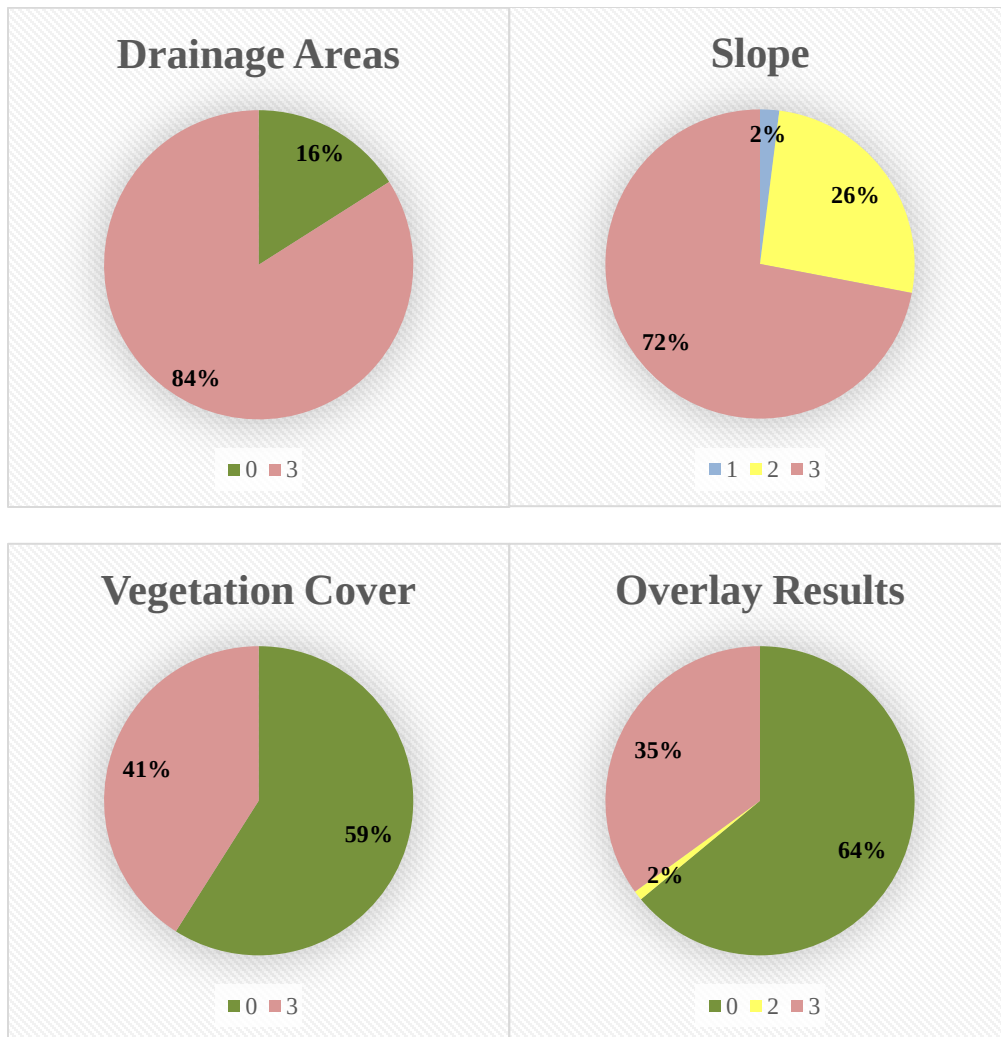


Figure 5.1. The vulnerability classes assigned to each reclassified analysis.

Survey-based Analysis

Respondents were concerned with environmental pollution via runoff, so an analysis was completed that highlighted areas vulnerable to this type of pollution. This allowed the local community to incorporate their knowledge and cultural values into the study. It is useful because it allows the research to take a direction that is most beneficial to the community. Replicating this in rural communities that have no access to GIS can

provide the means to perform analyses that can be distributed throughout the community and help promote local interests that can affect policy for land use planning.

Adoption Recommendations

As the rate of adoption timeline begins to move to the “early majority” phase, this is an ideal time to enhance marketing strategies to potential biodigester partners in the community. Thematic analysis showed a high response to community collaboration, protection of surface water, and economic value of the gas. There are many benefits to biodigesters, and these top three encompass environmental, social, and economic. Marketing these benefits as highest priority would be most likely to receive better feedback and adoption with future projects. A great opportunity discovered in the interviews was the use of a biodigester for ecotourism purposes.

The current biodigester recipients are a key source of knowledge to promote implementation. The bond shared between those of similar educational or occupational backgrounds as stronger than the bond between those coming from different backgrounds (De Tarde 1903). As they are more embedded in the community, it is now the role of the respondents to promote the projects and encourage their adoption in San Luis. Katz and Lazarsfeld introduced the concept of opinion leaders as “the individuals who were likely to influence other persons in their immediate environment” (1955). If current participants were to be the opinion leader, they would be better received as a community member and could increase participation in the projects.

The weighted overlay provided maps documenting areas of high risk for nonpoint source pollution due to runoff. Distributing this data throughout the community could

increase interest and participation in future projects. They should also be distributed to the respondents, who played a vital role in informing the analysis.

The method used of a participant-based GIS analysis is highly useful in designing analyses that can create change in the best interests of the community at hand. It provides a platform for participants' opinions and creates a tangible outcome from a study. In these cases where resources and GIS knowledge is limited, using frequencies from a semi-structured interview to rank importance on a suitability analysis gives the best explanation of local desires.

CHAPTER 6

CONCLUSION

This project used a method of creating a GIS suitability analysis based on semi-structured interviews. This hybrid approach allowed respondents to direct the suitability model, ensuring its applicability to the community of San Luis. Semi-structured interviews were used as a tool to gather information from twelve biodigester recipients. These interviews were analyzed using content analysis, identifying codes and recording their frequencies to identify community perceptions towards the project. The three codes with the highest frequencies were community collaboration, preemptive protection of water sources, and mitigation of wastewater.

The semi-structured interview responses guided community preferences regarding the installation of biodigesters in the area. It also provided quantifiable data that could be used when requesting funding or participation in future projects, identifying specific benefits. Quantifiable benefits included average monthly savings of 50% on energy costs three to four hours of cooking time. Few respondents identified ecotourism benefits as a motivator for owning a digester, though many identified ecotourism as a use of their property.

The attitudes and beliefs of the participants were incorporated into the study by using the theme frequencies to inspire and weight the analysis criteria. Results from the GIS suitability model revealed that 35% of the study area was highly vulnerable to

nonpoint source pollution. Biogas projects will continue to be developed in San Luis, shifting soon from the early adopters to the early majority in the diffusion of innovation theory, new strategies should be taken to emphasize use of the digesters other than a cooking gas. Now is the time to redirect marketing to potential participants, using the social, economic, and environmental benefits found by this study. Responses from the semi-structured interviews indicate that a cost-share model could be useful in future implementation. Six of the digesters failed due to insufficient protection, a problem that could potentially be avoided with construction oversight that approves cost share.

Future Research

Future research could include investigations into siting suitable areas for digester placement. A higher resolution data would provide opportunities to identify point source pollution, such as that from stables and barns. Soil data could contribute to a full evaluation of runoff and its capacity to absorb effluent discharge. ArcSWAT could be used to model nutrient loading in this particular landscape but would require calibration. Coffee production is a large industry in this area, producing a wastewater in production that could be treated by a biodigester. The byproduct of the coffee harvest process is water with a high sugar content, which creates a large potential for a biodigester. The semi-structured interview revealed the success of the digester to clean this sugar water, making coffee plantations an ideal target market for future projects. The weighted overlay analysis examines areas vulnerable to nonpoint source pollution to determine areas that would benefit from nonpoint interventions. Additional interviews conducted

with potential recipients could provide more insight to the desire to participate in these projects from a cultural perspective and track changes in attitudes in the future.

APPENDIX A

SURVEYS

The survey below was the semi-structured interview given to each respondent. It is listed first in English, then in Spanish. The survey was adopted from the Newcomer study (Newcomer 2005).

Section 1. Land Use

1-1. Of the following options, which of the following best represents the legal structure of your property?

- | | |
|--|---------------|
| 1. Single individual owner | Owner's name? |
| 2. In the name of multiple family members | Family name? |
| 3. In the name of a corporation | Company name? |
| 4. In the name of a non-profit association or foundation | Name? |
| 5. Other | |

1-2. For how many years have you held possession of this property?

_____ less than one year

_____ years (*note how many years*)

1-3. Do you live on this property full-time?

___ Yes

___ No

1-4. How many hectares (or monsanas) does your property measure?

1-5. Is a part of your property dedicated to working pasture land?

☐ Yes (# hectares = _____) (or mansana (=8,000m²))

☐ No

1-6. Is a part of your property dedicated to working agriculture?

☐ Yes (# hectares = _____)

☐ No

1-7. Is a part of your property dedicated to ecotourism?

☐ Yes (# hectares = _____)

☐ No

1-8. Which of the following best describes the type of crops you produce?

☐ A. Subsistence production for personal consumption

☐ B. Production for national commercial markets

☐ C. Production for export

☐ D. Production for both personal consumption and for

commercial markets

☐ E. Other

1-9. What is the primary potable water source for this property?

☐ A. Well on my property

☐ B. Community water source (Not ASADA aqueduct)

☐ C. San Luis Aqueduct

☐ D. Spring on my property

☐ E. River on my property

☐ F. River not on my property

___ G. Other

1-10. What is the primary agricultural water source for this property?

___ A. Well on my property

___ B. Community water source (Not ASADA aqueduct)

___ C. San Luis Aqueduct

___ D. Spring on my property

___ E. River on my property

___ F. River not on my property

___ G.

1-11. Are there any (*other*) watery areas on your property, such as rivers, streams, ponds, lagoons, ect?

___ Yes (*Please describe*)

___ No

1-12. Do you think it is important to protect the environment? What are the **most important** reasons you think it is to protect the environment?

1-13. Any other reasons?

1-14. Of all the reasons you just gave, which one is the most important to you?

1-15. Do the water sources on your property appear to be cleaner after the installation of the digester?

1-16. Has anyone tested this?

1-17. What positive effects did you see from the installation of the digester?

1-18. What negative effects did you see from the installation of the digester?

1-19. Is your biodigester currently in use?

1-20. (If no) why not?

1-21. (If because of a popped bag) How did the bag break?

Section 2. Motivations for Biodigestors

2-1. Do you listen to the radio in your house?

☐ Yes

☐ No

2-2. Do you listen to environmentally-focused programs on the radio?

☐ Yes

☐ No

2-3. Do you watch television in your house?

☐ Yes

☐ No

2-4. Do you watch environmentally-focused programs on the television?

☐ Yes

☐ No

2-5. Do you read any newspapers?

☐ Yes

☐ No

2-6. Do you read articles in newspapers about environmental issues?

☐ Yes

___ No

2-7. How did you learn about biodigestors? (*Mark all that apply*)

___ A. From a neighbor

___ B. A presentation in my community

___ C. I went to a meeting in a nearby community

___ D. Through an organization I belong to

___ E. From someone from UGA

___ F. Other

2-8. Can you briefly describe, in your own words- what is the purpose of the biodigestor? Why do you have a biodigestor on your property?

Please tell me whether you “completely agree”, “somewhat agree”, or “do not agree” with the statement.

Use the following codes to record answers:

A. completely agree

B. somewhat agree

C. do not agree

___ 2-9. *One owner said:* I requested to receive a biodigestor because, for me, it is important to protect the environment and nature.

___ 2-10. I requested to receive a biodigestor so I don't have to pay for other natural gas (like propane).

___ 2-11. I requested to receive a biodigestor area for the pleasure I feel for helping the environment.

___ 2-12. I requested to receive a biodigester because others in my family think it is important.

___ 2-13. I requested to receive a biodigester because it is profitable for the tourism that it attracts.

___ 2-14. I requested to receive a biodigester because, for Costa Rican culture, protection of nature is important.

___ 2-15. I requested to receive a biodigester because it is a moral and ethical duty to leave the Earth in a good condition, equal to or better than we found it.

___ 2-16. I requested to receive a biodigester because tourists from other parts of the world think it is important.

___ 2-17. I requested to receive a biodigester because I didn't have to pay for it.

___ 2-18. I requested to receive a biodigester although I didn't quite understand what it was.

___ 2-19. I requested to receive a biodigester because my friends think it is important.

___ 2-20. I requested to receive a biodigester because the resources I protect now will be worth more in the future.

___ 2-21. I requested to receive a biodigester because it is important to protect our watershed.

___ 2-22. I requested to receive a biodigester because it will be a valuable inheritance that I can give to my children.

___ 2-23. I requested to receive a biodigester for the public recognition it brings me.

___ 2-24. I requested to receive a biodigester because I had heard positive things about them from friends in the community.

Section 3. Capital Resources and Credit Access

3-1. If you were to borrow money to invest in your property, such as to buy a new piece of work-related machinery for planting or harvest, or to improve farm infrastructure, which of the following options would be the most likely source you would use for financing?

- ___ A. Bank
- ___ B. Development Association
- ___ C. Family member
- ___ D. Local cooperative
- ___ E. A grant from an agency
- ___ E. Other

3-2. How difficult would it be for you to obtain financing?

- ___ A. I probably could not get a loan
- ___ B. Difficult, but I could get a loan with a lot of effort
- ___ C. It's possible, and I would just have to fill out all of the paperwork and wait a certain time for approval
- ___ D. It's very easy, and I could get a loan within a few weeks
- ___ E. I don't know

3-3. Would you be willing to borrow money now for investing in your property in order to increase its long-term value?

☐ Yes

☐ No

Section 4. Demographic Information

4-1.

☐ Male ☐ Female

4-2. How old are you, according to the following ranges?

☐ A. Less than 25 years old

☐ B. Between 25-34 years old

☐ C. Between 35-49 years old

☐ D. Between 50-64 years old

☐ E. More than 65 years old

4-3. What is your highest level of formal education, given these following ranges?

☐ A. Incomplete primary school

☐ B. Completed primary school

☐ C. Incomplete secondary school

☐ D. Completed secondary school

☐ E. Incomplete undergraduate university

☐ F. Completed university degree

☐ G. Post-graduate university

☐ H. Other studies and training

4-4. What is your nationality?

- ☐ A. Costa Rican citizen: (Born in Costa Rica)
- ☐ B. Costa Rican citizen: (naturalized)
- ☐ C. Dual citizenship
- ☐ D. Foreign country

4-5. If you have a spouse or partner, what is his/her nationality?

- ☐ Costa Rican citizen: (Born in Costa Rica)
- ☐ Costa Rican citizen: (naturalized)
- ☐ Dual citizenship (Costa Rica and _____)
- ☐ Foreign country
- ☐ Not married

4-6. What is your primary occupation?

4-7. Do you have a secondary occupation from which you receive income?

- ☐ Yes (*Please specify:* _____)
- ☐ No

4-8. Which of the following best describes your average monthly income from all activities?

- ☐ A. Less than ₡100,000 per month (less than \$250)
- ☐ B. ₡100,000 – ₡200,000 per month (\$250 - \$500)
- ☐ C. ₡201,000 – ₡400,000 per month (\$501 - \$1,000)
- ☐ D. ₡401,000 – ₡800,000 per month (\$1,001 - \$2,000)

___ E. ₦801,000 – ₦1.2 million per month (\$2,001 - \$3,000)

___ F. ₦1.2 million – ₦1.6 million per month (\$3,001 - \$4,000)

___ G. More than ₦1.6 million per month (more than \$4,000)

4-9. Of this total monthly income, what portion comes directly from on-farm activities?

___ A. Less than 25%

___ B. Between 25% and 50%

___ C. Between 50% and 75%

___ D. More than 75%

Section 5. Energy Cost and Biodigestors

5-1. Before the installation of the biodigester, which fuel did you use to cook? How much did you pay for it per month?

___ A. Propane

___ B. Other type of compressed natural gas

___ C. Firewood (how much?)

___ D. Other _____

5-2. Did the biodigester save you money? If yes, how much per month?

5-3. How much would you be willing pay for a biodigester on your farm?

Now that we have finished, do you have any questions for me or thoughts to share on the project in general?

Formulario de Encuesta para los Destinatarios de Biodigestores en San Luis

Sección 1. Usos de Suelos

1-1. De las siguientes opciones, ¿cuál representa mejor la estructura legal de su propiedad?

___ A. A nombre de una sola persona ¿Nombre del dueño?

___ B. A nombre de varios miembros de familia ¿Quiénes son?

___ C. A nombre de una Sociedad Anónima ¿Nombre?

___ D. A nombre de una fundación, o una asociación sin fines de lucro

¿Nombre? _____

___ E. Otro (*Especifique, por favor:*

_____)

1-2. ¿Desde hace cuántos años tiene esta propiedad?

_____ menos de un año

_____ años (*Anote cuantos años*)

1-3. ¿Vive usted en la propiedad todo el tiempo?

___ Sí

___ No

1-4. ¿Cuántas hectáreas (o mansana) mide su propiedad?

1-5. ¿Se dedica una parte de la propiedad a pasto activo?

___ Sí (# ha = _____) (o mansana)

___ No

1-6. ¿Se dedica una parte de la propiedad a la agricultura?

___ Sí (# ha = _____)

___ No

1-7. ¿Se dedica una parte de la propiedad a eco-turismo?

___ Sí (# ha = _____)

___ No

1-8. ¿Cuál de las siguientes opciones representa mejor su forma de producción?

___ A. Producción de subsistencia para consumo personal

___ B. Producción para mercados comerciales nacionales

___ C. Producción para la exportación

___ D. Producción para el consumo personal y para los mercados

comerciales

___ E. Otra (*Describe, por favor:*

_____)

1-9. ¿Cuál es la principal fuente de agua potable para esta propiedad?

___ A. Un pozo en mi propiedad

___ B. Naciente comunal (NO acueducto ASADA)

___ C. Acueducto de San Luis (ASADA)

___ D. Una naciente en mi propiedad

___ E. La tomo de un río dentro de mi propiedad

___ F. La tomo de un río fuera de mi propiedad

___ G. Otra (*Especifique la fuente, por favor:*

1-10. ¿Cuál es la principal fuente de agua para usos agrícolas?

___ A. Un pozo en mi propiedad

___ B. Naciente comunal (NO acueducto ASADA)

___ C. Acueducto de San Luis (ASADA)

___ D. Una naciente en mi propiedad

___ E. La tomo de un río dentro de mi propiedad

___ F. La tomo de un río fuera de mi propiedad

___ G. Otra (

1-11. ¿Hay aguas en su propiedad, tales como nacientes, ríos, quebradas, lagunas, etc.?

___ Sí (*Especifique, por favor:* _____)

___ No

1-12. ¿Crees que es importante proteger el medio ambiente? ¿Cuáles son las razones **más importantes** por las cuales usted protege el medio ambiente?

1-13. ¿Alguna otra razón?

1-14. De todas las razones que me acaba de dar, ¿cuál es la más importante para usted, personalmente?

1-15. ¿Sus aguas parecen ser más limpias después de la instalación de la biodigestor?

1-16. ¿Alguien ha probado el agua para ver si era más limpia después de la instalación de la biodigestor?

1-17. ¿Cuáles efectos positivos ha visto usted, por el uso del biodigestor?

1-18. ¿Cuáles efectos negativos ha visto usted, por el uso del biodigestor?

1-19. ¿Está el biodigestor actualmente en uso?

1-20. (Cuando no) ¿Por qué no lo está usando?

1-21. (Cuando a causa de una bolsa rota) ¿Cómo se rompió la bolsa?

Sección 2. Motivaciones para Biodigestores

2-1. ¿Escucha radio en su casa?

___ Sí

___ No

2-2. ¿Escucha usted programas que tocan temas ambientales o de la naturaleza?

___ Sí

___ No

2-3. ¿Ven la televisión en su casa?

___ Sí

___ No

2-4. ¿Mira usted programas que tocan temas ambientales o de la naturaleza?

___ Sí (¿Cuáles? _)

___ No

2-5. ¿Lee usted el periódico?

___ Sí

___ No

2-6. ¿Lee artículos que se tratan de temas ambientales o de la naturaleza?

___ Sí

___ No

2-7. ¿Cómo o de dónde obtuvo información sobre los biodigestores? (**Marque todas las opciones que se apliquen.**)

___ A. Por un vecino o amigo

___ B. Una presentación en mi comunidad

___ C. Fui a una reunión en otra comunidad

___ D. Por una organización a la que estoy afiliado

___ E. Por una persona a UGA

___ F. Otra

2-8. ¿Me podría describir, brevemente y en sus propias palabras—¿Cuál es el propósito de un biodigestor? ¿Por qué tienen biodigestores en su propiedad?

Use lo siguiente para codificar sus respuestas:

A. completamente de acuerdo

B. más o menos de acuerdo

C. en desacuerdo = NO de acuerdo

___ 2-9. *Un finquero dijo: Yo solicité recibir un biodigestor porque, para mí, es importante proteger el medio ambiente y la naturaleza. ¿Está usted “completamente de acuerdo”, “más o menos de acuerdo”, ó “en desacuerdo” con esa frase?)*

- ___ 2-10. Yo solicité recibir un biodigestor porque así no tengo que pagar por otro gas natural (como propano).
- ___ 2-11. Yo solicité recibir un biodigestor porque me complace mucho cuidar el medio ambiente.
- ___ 2-12. Yo solicité recibir un biodigestor porque otros en mi familia creen que es importante.
- ___ 2-13. Yo solicité recibir un biodigestor porque es rentable por el turismo que me atrae.
- ___ 2-14. Yo solicité recibir un biodigestor porque, para la cultura costarricense, la protección de la naturaleza es algo importante.
- ___ 2-15. Yo solicité recibir un biodigestor porque es un deber moral y ético dejar la Tierra en una buena condición, igual o mejor que como la recibimos.
- ___ 2-16. Yo solicité recibir un biodigestor natural porque muchos turistas de otros países creen que eso es importante.
- ___ 2-17. Yo solicité recibir un biodigestor porque no tenía ningún costo para mí.
- ___ 2-18. Yo solicité recibir un biodigestor aunque no entendía muy bien de que se trataba.
- ___ 2-19. Yo solicité recibir un biodigestor natural porque mis amigos creen que es importante.
- ___ 2-20. Yo solicité recibir un biodigestor porque los recursos que estoy protegiendo ahora tendrán más valor económico en el futuro.

___ 2-21. Yo solicité recibir un biodigestor porque es importante proteger nuestra cuenca.

___ 2-22. Yo solicité recibir un biodigestor porque es un patrimonio valioso que puedo dar a mis hijos.

___ 2-23. Yo solicité recibir un biodigestor natural por el reconocimiento público que me produce.

___ 2-24. Yo solicité recibir un biodigestor porque había oído pensamientos positivos acerca de ellos dentro de la comunidad.

Sección 3. Recursos de Capital y Acceso al Crédito

3-1. Si Usted fuera a tomar un préstamo para invertir en su finca, ya sea para nueva maquinaria, para siembra o cosecha agrícola, o para mejorar la infraestructura, ¿cuál de las siguientes opciones sería la más probable que usted escogiera para conseguir el financiamiento?

___ A. El banco (*Especifique cuál banco, y su ubicación:*
_____)

___ B. La asociación de desarrollo

___ C. Mi familia

___ D. La cooperativa local (*Especifique cuál:*
_____)

___ E. Una beca de una agencia

___ F. Otra (*Especifique:* _____)

3-2. ¿Qué tan difícil sería obtener este financiamiento?

___ A. Probablemente, no podría conseguir un préstamo para invertir en mi finca.

___ B. Sería muy difícil, pero podría conseguir un préstamo con mucho esfuerzo.

___ C. Sería muy factible, sólo tendría que llenar todos los formularios y esperar cierto plazo para la aprobación.

___ D. Sería muy fácil. En pocas semanas podría conseguir el dinero.

___ E. No sé (*Si fuera posible, sería mejor que contestara unas de las opciones A-D.*)

3-3. ¿Estaría usted dispuesto a tomar un préstamo ahora para invertir en su finca, para que se aumente su valor a largo plazo?

___ Sí

___ No

Sección 4. Información Demográfica

4-1. ___ Hombre ___ Mujer

4-2. ¿Cuál es su edad, de acuerdo con los siguientes rangos?

___ A. Menos de 25 años

___ B. Entre 25 y 34 años

___ C. Entre 35 y 49 años

___ D. Entre 50 y 64 años

___ E. Más de 65 años

4-3. De los rangos de educación formal que le voy a leer, ¿cuál es el nivel más alto que usted ha alcanzado? (**ATENCIÓN: Ofrezcale una tarjeta con las opciones.**)

- ☐ A. Primaria incompleta
- ☐ B. Primaria completa
- ☐ C. Secundaria incompleta
- ☐ D. Secundaria completa
- ☐ E. Universitaria incompleta
- ☐ F. Universidad completa
- ☐ G. Universidad post-gradúo
- ☐ H. Otros estudios y/o capacitaciones (*Especifique:*

4-4. ¿Cuál es su nacionalidad?

- ☐ A. Costarricense por nacimiento
- ☐ B. Costarricense por naturalización
- ☐ C. Doble ciudadanía
- ☐ D. Extranjero (*Especifique:*)

4-5. Si tiene pareja(o) o esposa(o), ¿de qué nacionalidad es ella (él)?

- ☐ A. Costarricense por nacimiento
- ☐ B. Costarricense por naturalización
- ☐ C. Doble ciudadanía
- ☐ D. Extranjero
- ☐ E. No tengo cónyuge

4-6. ¿Cuál es su profesión u oficio principal?

4-7. ¿Tiene una profesión u oficio secundario, de la cual recibe ingresos?

___ Sí (*Especifique:*

_____)

___ No

4-8. De los rangos siguientes, ¿cuál describe mejor sus ingresos mensuales promedio provenientes de todas las actividades/fuentes de ingreso?

___ A. Menos de ¢100.000 por mes (menos de \$250)

___ B. ¢100.000 – ¢200.000 por mes (\$250 - \$500)

___ C. ¢201.000 – ¢400.000 por mes (\$501 - \$1.000)

___ D. ¢401.000 – ¢800.000 por mes (\$1.001 - \$2.000)

___ E. ¢801.000 – ¢1.2 millones por mes (\$2.001 - \$3.000)

___ F. ¢1,2 millones – ¢1,6 millones por mes (\$3.001 - \$4.000)

___ G. Más de ¢1,6 millones por mes (más de \$4.000)

4-9. Del total de sus ingresos mensuales, ¿qué proporción proviene directamente de las actividades productivas de su finca?

___ A. Menos de 25%

___ B. Entre 25% y 50%

___ C. Entre 50% y 75%

___ D. Más de 75%

Sección 5. Energía y Biodigestores

5-1. Antes de la instalación de su biodigestor- que el combustible usó para

cocinar? ¿Cuánto paga normalmente por cocinar cada mes?

___ A. Propano

___ B. Otro tipo de gas natural

___ C. Leña (cuántos?)

___ D. Otro _____

5-2. ¿El biodigestor a ahorrar dinero? (En caso afirmativo) ¿Cuántos?

5-3. ¿Cuánto pagaría por la instalación de un biodigestor en su granja?

Ahora que terminamos, ¿tiene usted alguna pregunta que hacerme, ya sea sobre la investigación, cómo vamos a analizar los datos u otra cosa?

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