Composting: A New Solution to Panama's Waste Problem

An analysis of food and vegetative waste production and disposal at La Ciudad del Saber to pilot a large scale composting program in Panama.

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Abstract

Worldwide disposal of organic waste in landfills creates many environmental and health problems. Landfilling organic waste contributes to global climate change and contamination of water sources. In Panama, increased waste production threatens local wildlife and human health because of ineffective waste disposal practices. Our project assisted La Fundación Ciudad del Saber (FCdS) in laying the groundwork for a pilot composting program for food and vegetative waste that is technically feasible and culturally transformative. By collecting information through interviews, waste audits, and surveys, we discovered that La Ciudad del Saber (CdS) disposes of their waste at an unsanitary landfill, contributing to the endangerment of the environment and public health. We also determined the mass and volume of compostable waste produced at key locations at the CdS. To help the FCdS reduce their impact on the environment, we developed recommendations for a compost program with high levels of participation and efficiency.

Acronyms and Definitions

Acronyms:

AAUD: Autoridad de Aseo Urbano y Domiciliario, Panama's municipal waste authority
CdS: Ciudad del Saber (City of Knowledge), a model city at former US military base Fort Clayton in Panama City
FCdS: Fundacion Ciudad del Saber (City of Knowledge Foundation), a nonprofit organization that manages the CdS campus and pilots many environmentally sustainable projects.

Definitions:

Cerro Patacón: The spanish name given to Panama's only landfill that services Panama City and the surrounding areas.
Composting: The process of decomposing organic materials into a nutrient rich fertilizer
La Plaza restaurant complex: a food court at La Ciudad del Saber with almost 30 restaurants and shops
Multiworks: The private landscaping company contacted by the FCdS to manage the grounds and dispose of all vegetative waste
Organic waste: Waste that is of biological origin such as food, paper, and yard waste
Municipal solid waste: All forms of solid waste that is thrown away, commonly referred to as just "garbage."
Vegetative waste: Organic matter (such as grass clippings and leaves) that comes directly from plants. Mangos fallen from the trees are included in the vegetative waste until they are introduced for composting. Their high nitrogen content classifies them as food waste in that circumstance.
Leachate: A mixture of rainwater and liquid from organic matter that collects chemicals and contaminants as it runs to the bottom of the landfill. Leachate can contaminate groundwater as it seeps into the soil
Sanitary landfill: A site where waste is isolated from the environment until most waste has decomposed completely.
Open air dumps: Are locations where solid wastes are disposed of in a manner that does not protect the environment, are susceptible to fires, and are unprotected to the elements, vectors and scavengers

Executive Summary

In developing countries, the rapid increase in waste production outpaces the development of adequate waste treatment programs, creating health and environmental hazards. Panama, a rapidly developing country, faces unique waste disposal challenges because of government corruption, inefficient collection, and a lack of social organization for environmental activism (Castro, private correspondence). As a result, almost all waste in Panama is left untreated. The only landfill in Panama, Cerro Patacón, is an unsanitary landfill that pollutes the environment and threatens public health.

In Cerro Patacón, organic waste significantly contributes to the production of methane and leachate. Leachate is a toxic liquid produced from landfills that is known to contaminate groundwater resources. Even if preventative measures are taken to contain leachate in landfills, leachate will eventually leak into the environment (Raghab, Meguid, & Hegazi, 2013). Methane, a flammable greenhouse gas, contributes significantly to global climate change and landfill fires. Eliminating organic waste from landfills could reduce methane emissions by as much as 90% (H. G. Bringemer, 1987).

Composting presents one solution to eliminating organic waste in landfills (Hoornweg & Bhada-Tata, 2012). Composting is the process of recycling organic waste into a nutrient rich soil known as humus. This humus has the potential to remedy two environmental threats faced by Panama: soil erosion and agricultural runoff.

No organization in Panama is better posed to test composting organic waste than La Fundación Ciudad del Saber (FCdS), a nonprofit organization that helps lead environmental sustainability in Panama. The FCdS manages La Ciudad del Saber (CdS), a 120-hectare campus (nearly 300 acres) that rents space to companies, schools, and government organizations. The FCdS could set an example for the rest of Panama by implementing a large scale composting program for others to model.

Project Goal, Research Questions, and Methodology.

The goal of this project was to assist La Ciudad del Saber in laying the groundwork for a pilot composting program that is technically feasible and culturally transformative. To accomplish this goal, we pursued the following research objectives:

1. Assess compostable waste disposal practices in place at La Ciudad del Saber
2. Estimate the mass, volume, and composition of food and paper waste produced at La Plaza restaurant complex and vegetative waste from the CdS campus
3. Investigate cultural obstacles that could affect the success of a pilot composting program at La Ciudad del Saber
4. Investigate stakeholder interests (the FCdS, La Plaza restaurant complex workers, and restaurant owners) and knowledge gaps related to a pilot composting program

To research these questions, we:

1. Interviewed representatives of the FCdS (La Fundación Ciudad del Saber)
2. Interviewed representatives from the FCdS and companies that dispose of organic waste at the CdS
3. Toured the landfill Cerro Patacón
4. Conducted a waste audit at the CdS
5. Surveyed Panamanians from the CdS and a local mall
6. Surveyed stakeholders such as restaurant owners at La Plaza restaurant complex

Findings.

We examined the current waste disposal system at La Ciudad del Saber, estimated compostable waste production, and identified potential problems that could affect a successful composting program at the CdS. Our findings are summarized below.

Objective 1: Assess waste disposal practices at La Ciudad del Saber.

Finding 1: Organic waste from the entire CdS campus is disposed of at the landfill Cerro Patacón, contributing to the landfill's environmental pollution, which results in health hazards. Waste from the CdS is disposed at Cerro Patacón, an unsanitary landfill (an unsealed landfill with little to no treatment facilities), which contaminates the surrounding environment. Organic waste disposed at Cerro Patacón creates two main environmental pollutants that threaten public health: leachate and methane gas. Leachate contaminates water sources, and methane contributes to global climate change and landfill fires.

Finding 2: Multiworks and the AAUD are inconsistent when they pick up trash at the CdS campus and often leave uncollected waste across campus. Multiworks often leaves vegetative waste in bags across campus for days on end.The AAUD is unreliable and unsanitary in their collection of trash at the CdS. The AAUD often comes several days late for trash collection, resulting in trash bags piling up at disposal and collection sites. Uncollected waste not only creates an eyesore, but it also provides food, shelter, and breeding grounds for a variety of scavengers such as rodents and insects. These organisms can carry and spread disease (Hoornweg & Bhada-Tata, 2012 p. 6).

Objective 2: Estimate the amount of food waste produced at La Plaza restaurant complex and compostable vegetative waste produced at the CdS campus

Finding 3: The total mass and volume of compostable waste produced per week from Multiworks and at La Plaza restaurant complex are: 6.1 tonnes (43.2 m3) during rainy season, 8.2 tonnes (88.2 m3) during dry season, and 11.7 (64.2 m3) tonnes during mango season. These calculated totals of compostable waste produced at La Plaza restaurant complex and from Multiworks are a high estimate. The FCdS requested we provide a high estimate so they could handle waste fluctuations, and be prepared for the highest amount of waste that could reasonably be expected. Our data was derived from a variety of sources including our waste audit, interviews, and disposition receipts.

Finding 4: Compostable vegetative waste production and composition vary across each of the three seasons: dry season (18 tonnes per week), rainy season (11 tonnes/week), and mango season (17 tonnes per week). We compiled data from each of the three seasons: dry season (December to March), rainy season (April to November) and mango season (June to August). Our analysis showed significant differences in the amount and composition of compostable vegetative waste produced.

Finding 5: Most of the waste produced by La Plaza restaurant complex is compostable; this accounts for 95% of the mass, and 65% of the volume of the total waste produced at La Plaza restaurant complex. La Plaza restaurant complex represents the largest food waste source our audit discovered on the CdS campus. Almost all of the mass and more than half of the volume produced at La Plaza restaurant complex is compostable.

Finding 6: Most of the waste produced at the Metropolitan (MET) school is compostable; this accounts for 95% of the mass, and 70% of the volume of the total waste produced at the MET School. Because the Metropolitan School features a vegetable-heavy lunch program, they produce a greater volume percentage of food waste in their cafeteria than La Plaza restaurant complex.

Objective 3: Investigate potential cultural obstacles that could affect the success of the program.

Finding 7: While most Panamanians understand that Panama faces growing waste challenges, their limited knowledge of sustainable practices and cultural habits regarding waste disposal prevent them from separating their waste. Our survey results showed that approximately 1 in 10 Panamanians know what composting is. Our interviews with Dr. Castro, an environmental historian, and Sandra Icaza, a community and culture specialist, backed up our results. They explained that even though most Panamanians understand Panama faces a waste problem, this knowledge does not directly translate to action.

Objective 4: Identify stakeholder concerns and knowledge gaps

Finding 8: Most of the restaurant owners (80%) at La Plaza restaurant complex believed that separating their waste would not affect their business and all restaurant workers felt separating waste would not place a significant burden on their jobs. Interviews with five La Plaza restaurant complex restaurant owners and ten restaurant workers showed that most of them (four out of five) do not believe that separating their organic waste from regular waste on a daily basis would have any negative effects on their business. One owner even said that waste separation would actually be a positive practice to incorporate in their practices, stating that it would be "easier to take out the trash [in separate bags]."

Recommendations.

1. To ensure high levels of participation, we recommend informing people who live and work at the CdS about the new composting system by implementing a poster campaign around campus, emailing residents and businesses, and posting information about composting on social media sites. Poster campaigns would be a simple, yet effective way to inform people about the composting program and the process of composting. Based on our research and surveys of people in La Plaza restaurant complex, posters should contain bolded titles and make good use of pictures.

2. To minimize the personnel needed to maintain the compost program, waste should be sorted when it is thrown away and the organic waste should be placed in a semi-automated composting system. Maintaining a compost system can be expensive because of labor cost. To minimize the burden on existing maintenance personnel, and avoid the need of hiring additional staff, the system should require minimal processing.

3. To be prepared for the maximum amount of waste, the FCdS should develop a system capable of storing and composting approximately 11.7 tonnes (88.2m3) of organic waste per week. The FCdS is currently interested in the Pila de Aireación Mixta composting unit from EARTHGreen Colombia. This system is capable of handling this amount waste for 25-day compost cycles. We recommend the FCdS continue pursuing a semi-automated system like the Pila de Aireación Mixta.

4. To minimize any negative impacts the compost heaps could have on those who work and live at the CdS, the compost system should not be located near highly populated areas. The FCdS has concerns about smell and the attraction of vermin. Although compost does not smell if processed correctly, it is easy to accidentally create smelly compost. To further mitigate these concerns, we recommend that all heaps be covered with a layer of sawdust or dirt. This prevents any possible odors from escaping and reduces the attraction of vermin.

5. To expand the composting program to include all CdS buildings, we recommend a gradual three phase rollout to ensure quality control and allow time to form partnerships. The composting program will first include food waste from La Plaza restaurant complex and vegetative waste from the entire campus. Once the program has been well established, it can be easily expanded to include other entities on the CdS campus including residences, schools, and businesses.

6. To ensure a successful composting program at the CdS, we recommend future projects in the following areas: To continue the development and implementation of the FCdS's pilot compost program, we recommend projects to perform a residential waste audit and develop a business plan for selling compost. To continue the exploration of Panama's waste crisis, we also recommend a study of low-income communities most impacted by the trash problem and how composting could be a solution for these communities.

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1 Introduction

Global waste production is increasing at an alarming rate: in the next decade, waste generation worldwide will nearly double (World Bank, 2012a). Much of this increase comes from the rapid industrialization of developing countries. In addition, developing countries usually lack adequate waste treatment programs, leaving waste untreated or improperly disposed. These unsanitary disposal practices create many environmental problems and health threats including landfill fires and water contamination.

No other source of waste contributes more to global waste production and its problems than organic waste (Hoornweg & Bhada-Tata, 2012). Decomposing organic waste in landfills creates many environmental problems, such as greenhouse gas emissions and leachate. Methane, a flammable greenhouse gas, is a by-product of organic waste decomposition in landfills that provides fuel for landfill fires. These fires release toxins into the air which cause respiratory problems for people living near the landfill. Leachate is a toxic liquid resulting from rainwater and liquid from decomposing organic matter that collects chemicals and contaminants as it runs through a landfill. If left untreated, leachate could leak into the ground and contaminate groundwater. Together, these by-products of organic waste decomposition present health concerns to municipalities that surround landfills.

In Panama, improper waste disposal in dumps and unsanitary landfills (an unsealed landfill with little to no leachate treatment facilities) threatens public health and the environment. Organic waste in these disposition sites attracts vermin, pollutes water sources, fuels landfill fires, and creates unsanitary living conditions for people who live in communities near landfills. Even sanitary landfills in Panama would not solve all the problems created by landfilling organic waste because methane would still escape into the atmosphere and leachate would eventually leak from the landfill.

Composting, the process of transforming organic waste into nutrient rich soil, presents a viable solution to many of the environmental and health threats associated with waste disposal because almost $\frac{2}{3}$ of all waste in Panama is organic (Hoornweg & Bhada-Tata, 2012). Composting would not only divert a significant portion of waste from landfills, but it would also solve several other environmental threats Panama faces, such as soil erosion and agricultural runoff.

No organization in Panama is better posed to test composting as a solution to Panama's waste problem than the nonprofit organization, La Fundación Ciudad del Saber (FCdS). The FCdS works to improve the lives of Panamanians by promoting sustainable development at La Ciudad del Saber (CdS) (Ciudad del Saber, 2015). The CdS was a former US military base located in Clayton, Panama City that now houses many companies, schools, and government organizations. Due to the large size of its campus (nearly 300 acres), the CdS has the potential to show Panama that composting is a viable solution to the waste problem.

The goal of this project was to assist La Fundación Ciudad del Saber in laying the groundwork for a pilot composting program for compostable waste that is technically feasible and culturally transformative. To lay the groundwork for a composting system for La Ciudad del Saber, the team pursued four objectives:

1. Assess compostable waste disposal practices in place at La Ciudad del Saber
2. Estimate the mass, volume, and composition of food and paper waste produced at La Plaza restaurant complex and vegetative waste from the CdS campus
3. Investigate cultural obstacles that could affect the success of a pilot composting program at La Ciudad del Saber
4. Identify stakeholder interests and knowledge gaps regarding composting

Our research helped us provide the FCdS with recommendations for how to initialize a pilot composting program. We hope that composting at the CdS will be a success and will help jump-start composting across Panama.

2 Background

Panama faces a growing waste problem. Organic waste represents a significant portion of the overall waste problem. Improper waste disposal and increasing industrialization intensifies the harmful effects of organic waste in landfills. In this chapter, we examine the following topics:

1. The global organic waste problem
2. How unsanitary waste disposal in Panama threatens public health and the environment
3. Composting as a potential solution to Panama's waste problem
4. Lessons learned from other compost programs
5. La Ciudad del Saber as a pilot program for Panama

2.1 The Global Organic Waste Problem: Composting as a Solution

Increasing waste production across the globe poses a grave threat to the environment (Breen, 2012). In 2007, 2.12 billion metric tonnes of waste were disposed of worldwide (United Nations Environment Programme, 2009). This is equivalent to 2% of all biomass on earth (Wolfram Research, n.d.). By 2025, global waste generation is expected to double (World Bank, 2012a). Global waste production continues to increase because many countries around the world are experiencing rapid industrialization and population growth. The waste production of developing countries and cities is growing faster than in developed countries. For example, Dubai in The United Arab Emirates produces three times more waste than Los Angeles, despite having almost half the population (Breen, 2012).

Growing waste production presents a significant problem for developing nations. Many developing countries lack the infrastructure needed to responsibly dispose of their increasing waste (Diaz, 2011). These nations have outdated legislation to manage waste, resulting in sporadic collection and unregulated dumping. The most feasible method of disposal for these countries are open landfills and dumps (Taiwo, 2011). These unsanitary disposal practices result in environmental contamination.

Organic waste as a global problem. No other source of waste contributes more to global waste production and its problems than organic waste. In total, organic waste composes 63% of all waste produced worldwide (Hoornweg & Bhada-Tata, 2012). Organic waste is the biodegradable component of waste that is of biological origin, including food, paper, and vegetative waste (The Environment Protection Authority of South Australia, 2009). In developing countries, organic waste represents an even larger portion of waste production than in developed countries, as shown in Figures 1a and 1b (World Bank, 2012b).

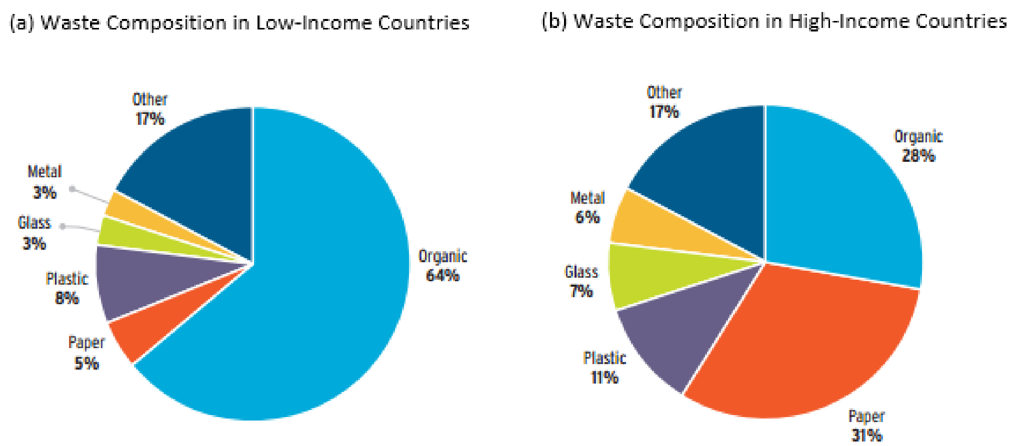

Figure 1: Waste compositions of low and high income countries (World Bank, 2012).[1]

The decomposition of organic waste in landfills and dumps creates an unnatural process because these disposal sites have anaerobic (without oxygen) conditions. Organic waste in landfills cannot decompose as efficiently as in nature because aerobic (requiring oxygen) bacteria cannot survive in landfills. A study found that after 5-6 years, less than a third of organic waste decomposed in a landfill (Eleazer, 1997). It normally takes less than a year for organic waste to decompose in nature. As a result of these unnatural anaerobic conditions, landfilling organic waste creates several environmental problems.

The anaerobic decomposition of organic waste in landfills contributes significantly to global climate change, producing 12% of global methane emissions. Methane is a greenhouse gas that is 21 times more powerful at trapping solar energy than carbon dioxide, making methane a heavy contributor to climate change (United States Environmental Protection Agency, 2014). Since methane production in landfills is almost exclusively from decomposing organic matter, this is how organic waste in landfills contributes significantly to global climate change (EPA, 2006). Even the most effective landfill methane capturing system still allows 25% or more of methane produced to escape into the atmosphere (US Composting Council, 2011).

Methane, a highly flammable gas, is known to start landfill fires. It readily combusts when it accumulates to concentrations of over 5000 ppm (5% of air composition), creating a potentially dangerous situation for those who work and live nearby (Matheson Gas Products, 2001). For example, if someone lights a lighter or creates a spark near the biogas escaping from a landfill, they could accidentally set the whole landfill on fire. Landfill fires across the world have caused serious injury and even death in some rare cases (TriData Corporation, 2002).

[1]The author elected to represent paper waste separately from organic waste, however, paper waste is in fact organic waste.

In landfills, organic waste contributes to the production of leachate, a toxic liquid that can contaminate the environment. Leachate is formed when liquid from rainwater and organic matter runs through a landfill and collects chemicals and contaminants on its way to the bottom. To almost entirely eliminate leachate production, landfills must be both protected from rainwater and contain no organic waste.

While sanitary landfills can help protect the environment against leachate contamination through impermeable liners and leachate treatment systems, leachate can still leak from the bottom of a sanitary landfill through cracks in the liner. (Raghab, Meguid, & Hegazi, 2013). Eventually all liners will tear or crack, allowing leachate to seep into the ground (US Environmental Protection Agency, 1982). Many developing nations do not implement sanitary landfills, allowing leachate to flow uncontrolled into the environment. This creates an even larger challenge for leachate management.

Rivers, groundwater, and other surrounding bodies of water contaminated by leachate create harmful environmental and health problems (Hoornweg & Bhada-Tata, 2012 p. 27). In rivers, just one gallon of leachate per 10,000 gallons of water can lower oxygen levels enough to threaten fish survival (Rector & Stroud, 2009). In addition to the detrimental environmental effects, humans who receive drinking water from these contaminated sources are at a much larger risk of developing birth defects and certain types of cancer (Taylor, 1999).

Composting as a possible solution. While no single method can solve the global waste dilemma, composting presents a viable solution to eliminating organic waste from disposal in landfills. Composting is the process in which organic matter decomposes in the presence of aerobic bacteria (bacteria reliant on oxygen), which turns into a nutrient rich soil known as humus. While all organic matter can be composted, large pieces of organic matter and matter of animal origin may require shredding or large composting piles to break down in a timely manner (The Royal Horticultural Society, 2015).

Removing organic waste from landfills can greatly reduce leachate production and methane emissions up to 90% (H. G. Bringemer, 1987). By diverting organic matter to a compost facility, health hazards to rural communities would be reduced. In addition, compost produces fertile soil that can be used to solve other environmental problems not directly related to waste, such as agricultural runoff and soil erosion.

Composting is gaining momentum as a responsible organic waste disposal method in developed countries, such as the United States. As of 2012, the United States had 3285 active large scale composting sites to generating 17.6 metric tonnes (19.4 million US short tons) of compost every year (Platt, Goldstein, & Coker, 2014). However, many cities and towns in the US still lack composting programs because most Americans see composting as an “extra chore” and “a stinking rotten mess” (Teitell, 2015). These negative attitudes toward composting have hindered the composting movement in the US. Despite these obstacles, compost programs are still growing momentum because of a cultural desire to be environmentally sustainable.

Historians and anthropologists have examined how people perceive waste and waste collectors around the world. When confronted with images of waste, people elicit emotional responses such as "disgust, abjection, and fear of contamination" (Keeling, 2012). These powerful negative emotions often transfer to waste collectors due to the associate effect. Some South Asian cultures with caste systems designate waste collectors as the lowest caste. The waste collectors are known as the "untouchables" because they are meant to be segregated from society to prevent contamination (Sharma, 2014). These cultural stigmas can hinder the adoption of alternative waste disposal methods, such as composting, as well as contribute to the perpetuation of poor waste disposal practices.

2.2 Organic Waste Disposal in Panama: A Threat to Public Health and the Environment

According to Gabriel de la Iglesia, the General Secretary of Panama's waste authority, Panama is 30 years behind in waste management compared to other Latin American countries such as Costa Rica and Colombia. This is due to Panama's unsanitary disposal sites and lack of recycling programs (de la Iglesia, private correspondence). This gap is a result of political conflicts, lack of functioning equipment, misuse of investments, and lack of cultural awareness (Jiménez & Muñoz, 2013). The landfill that services all of Panama City is known as Cerro Patacón. Cerro Patacón was built as a sanitary landfill. Unfortunately, improper upkeep and malpractice have transformed Cerro Patacón into something far from a sanitary landfill.

Leachate from Cerro Patacón is particularly toxic because, "everything is thrown into Cerro Patacón" (de la Iglesia, private correspondence). This includes hospital waste, batteries, and other toxic waste such as residual waters and narcotics. Batteries leak acids that cause lethal diseases, such as cancer (Banfield, 2013). An example of a battery in Cerro Patacón can be seen in Figure 2. Hospital waste is currently left untreated and dumped in the open air. These harmful wastes are made more threatening to Panama's public health because of the ineffective and insufficient leachate treatment system at Cerro Patacón (de la Iglesia, private correspondence).

Figure 2: An incorrectly disposed battery at Cerro Patacón

At Cerro Patacón, leachate floods into the surrounding environment. The leachate treatment plant at Cerro Patacón only has the capacity to treat about one-fifth of all leachate produced. As seen in Figure 3, the three leachate pools at Cerro Patacón have flooded to become one large body of water. Leachate also floods public roads, residential areas, and two nearby rivers, Rio Mocambo and Rio Abajo (de la Iglesia, private correspondence). Leachate flooding from Cerro Patacón onto the public road can be seen in Figure 4. Even if sufficient leachate treatment pools were implemented at Cerro Patacón, leachate would eventually leak from the landfill through cracks in the liners (US Environmental Protection Agency, 1982).

Figure 3: Flooded leachate treatment pools at Cerro Patacón

Figure 4: Leachate overflowing the road at Cerro Patacón

Shockingly, little information is available regarding the state of Panama's groundwater resources, including water level and contamination reports. According to one environmentalist, Raisa Banfield, leachate from Cerro Patacón contaminates groundwater in Panama (Banfield, 2013). The particulars of this contamination are not known. What is known, however, is that two-thirds of Panama's population depends on groundwater from a watershed that Cerro Patacón sits on top of (World Bank, 2008, p. 57). This large water resource could be in danger of contamination, or it may already be contaminated from Cerro Patacón and other open dumps called vertederos (de la Iglesia, private correspondence). The locations of these vertederos are shown in Figure 5 and a picture of a vertedero is shown in Figure 6. If significant amounts of leachate and other toxins contaminate this groundwater, the resulting health effects could be widespread and devastating.

Figure 5: Locations of 63 vertederos (open dumps) in Panama (de la Iglesia, 2015)

Figure 6: A vertedero in Panama (de la Iglesia, 2015)

Cerro Patacón also has a history of catching fire, resulting in health threats to Panama City. Methane produced from the decomposition of organic waste fuels landfill fires and makes them extremely difficult to put out. The most recent of these fires was in 2013. The Urban and Household Authority of Panama claimed this fire was the worst so far; more than 30 acres of garbage caught fire and burned for over four days (Campagna, 2013). A picture of this fire can be seen in Figure 7. The landfill fire also created significant air pollution in Panama's urban areas, which caused respiratory infections such as bronchitis (World Bank, 2008, p. 35).

Figure 7: Cerro Patacón 2013 fire (en.di., 2013)

2.3 Composting as a Potential Solution to Panama's Waste Dilemma

The greatest advantage of composting is not only its cost effectiveness, but also the plethora of benefits it brings to the environment. Two of Panama's greatest environmental threats, soil erosion and agricultural runoff, can be remedied with compost. When implemented correctly, composting demonstrates a technically feasible and economically sustainable waste practice.

Protection against soil erosion. Soil erosion presents a major environmental concern for Panama, which can be alleviated with the use of compost. Soil erosion is the process by which earth is worn away. Erosion creates environmental harm because loose sediment can infiltrate water supplies (Rutledge et al., n.d.). Soil erosion also creates many problems such as compaction, increased soil salinity, nutrient degradation, and loss of soil structure. Panama currently struggles with soil erosion, especially around the Panama Canal (Lee, Lorch, & Melong, 2012). Compost can help solve this environmental issue by encouraging plant growth, which keeps the soil in place. Compost is especially helpful in protecting soil on steep slopes, where erosion is most severe. Mounds of compost can be strategically placed on these slopes to slow rain and field water runoff (Environmental Protection Agency, 1997).

Protection against agriculture runoff. Composting reduces the need for chemical fertilizers in agriculture, which decreases water pollution (United States Environmental Protection Agency, 2014). Agricultural runoff creates another major environmental challenge in Panama. It pollutes rivers and leaks into the ocean— threatening aquatic life and the fishing industry (Lee, Lorch, & Melong, 2012). Chemical treatments are commonly used to remove molds and fungi from soil. Microorganisms in compost piles consume mold and fungi contaminants, thereby reducing the need for chemical treatments. Compost can even clean soil contaminated by chemical waste (United States Environmental Protection Agency, 2014).

Cost effectiveness. Composting in Panama has the potential to be as cost effective as waste disposal in landfills. For a middle income country such as Panama, it costs between $20 and $75 to compost one ton of organic waste. The cost of waste disposal in landfills is between $25 and $65 per ton. Unlike waste disposal in landfills, compost can be sold for up to $100 per tonne, potentially negating collection and production costs, and even producing revenue (Hoornweg & Bhada-Tata, 2012 p. 46). Effective management could prove composting economically advantageous over landfill disposal.

The benefits of composting are mostly seen in environmental impacts and community awareness (Hoornweg et al., 1999 p.14). For example, In India, at one labor-intensive composting facility, one tonne of compost took $34.20 to make and was sold for $40. This made a profit of $5.80 per tonne (Harper, 2004 p. 33). While profit margins for compost are generally not high in developing countries, composting does present an economically sustainable waste solution for a developing country like Panama. As mentioned earlier though, the benefits of composting are mostly seen in alleviating various environmental threats and in improving agriculture.

2.4 Successful Implementation Of Composting: Lessons Learned

Because many organizations around the world have implemented composting systems, we can learn what common factors led to successful or unsuccessful campaigns. The following five elements were common factors that led to successful compost programs with high levels of participation and low economic deficit.

1. Pre-sorting waste. Pre-sorting waste reduces the costs associated with and improves the quality of compost. Case studies from the European Union revealed that pre-sorted waste collection reduces the amount of manpower needed to compost. Furthermore, case studies from Sri Lanka show that mixed waste cannot be separated properly to produce uncontaminated compost (Harper, 2004 p. 47).

2. Informing people about the process. People are more likely to contribute to a composting program once they are familiar with the process and the benefits of composting. The Katherine Delmar Burke School in San Francisco, California noticed that the students who refused to participate did not have a solid understanding of composting (San Francisco Recycling Program, 2000). Effective education campaigns involved strong advertising and explanations about what composting is and what you can compost.

3. Advertising the program. People are much more likely to participate in a composting program if they know about it and how it works. In the European Union, countries that invested more money on advertising and raising local awareness saw higher levels of community participation (Wallström, 2000). For example, the Montejurra composting project in Spain was successful due to its large-scale publicity campaign. The government conducted campaigns in schools and retirement homes, and advertised through newspapers, television, and radio stations. This not only led to public acceptance, but also to active participation from the community (Wallström, 2000).

A case study from public elementary schools in San Francisco, California, found that posters were most effective at getting students to separate the right materials for a compost system (San Francisco Recycling Program, 2000). In Oeiras, Portugal, the most successful method of promotion was door-to-door promotion with delivery of informational pamphlets. Although this method of promotion required more investment, it sparked local interest in the project and made the community more aware of environmentally sustainable waste practices (Wallström, 2000).

4. Choosing an appropriate system. In developed countries where the cost of labor is high, the most economically sustainable compost systems are automated systems that only require a few personnel to maintain (Wallström, 2000). In developing countries, fully mechanized compost systems are not recommended because there tends to be a lack of skilled workers capable of handling the daily operations and fixing mechanical breakdowns (Hoornweg, Thomas & Otten, 1999 p. 11). In general, the amount of labor needed for a compost system in developing countries should depend on the cost of labor.

5. Marketing the compost. Finished compost can be sold to local farmers and community gardeners to cover the cost of running a composting program. In developing countries, marketing compost may be difficult at first because people are not aware of what compost is and its benefits (Harper, 2004 p. 34). The largest market for selling compost in some developing countries are organic farmers (Harper, 2004 p. 56). Organically certified compost can fetch a higher price for finished compost; however, compost production costs may also increase because organic certification requires higher quality compost. In addition, the certification itself can be costly to acquire and maintain. It is important to asses if organically certifying compost will be cost effective (Harper, 2004 p.33).

Local farmers must also be educated on the benefits of using compost. The results of using compost will only begin to show after 3 to 4 years as opposed to immediate results with inorganic fertilizers. Using compost as opposed to inorganic fertilizer promotes long term sustainability and fertility. However, large amounts of compost are needed at first to restore damaged soil from the overuse of inorganic fertilizer (Harper, 2004 p.33). The first year of using compost can be more expensive so it could be difficult to convince farmers that using compost would be a good investment. In subsequent years, farmers should start seeing savings and a significant improvement in land quality (Harper, 2004 p.57).

2.5 La Ciudad Del Saber: a Pilot Program For Panama

La Fundación Ciudad del Saber (FCdS) is a private nonprofit organization located in Clayton, Panama City that strives to be an environmental leader for sustainable development in Panama. The FCdS manages La Ciudad del Saber (CdS), a 120-hectare campus (nearly 300 acres) that rents space to companies, schools, and government organizations (see figure 8 for a map of the CdS). The FCdS strives to eliminate negative environmental impacts in all parts of their operations, including waste disposal, so they are interested in pursuing waste disposal alternatives such as composting. Dr. Guillermo Castro, an environmental historian, explained that "[La Ciudad del Saber] is a project for the whole country" (Castro, personal correspondence). Since no large scale composting projects exist in Panama, the success or failure of a composting program at the CdS will impact Panamanian perception of composting.

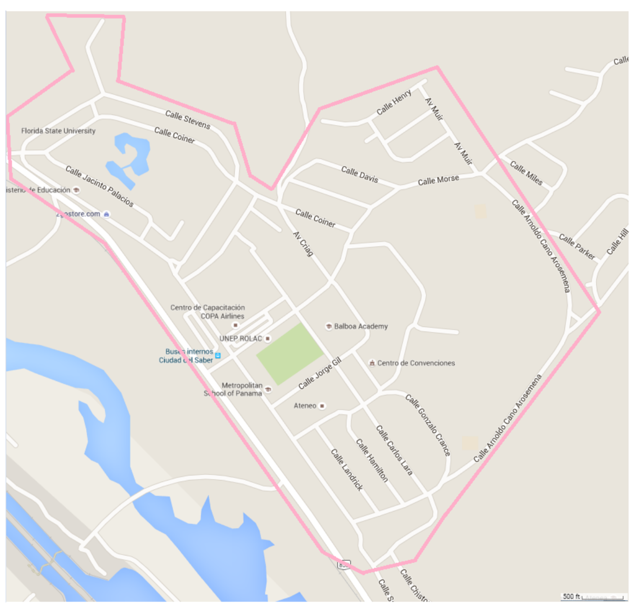

Figure 8: Map of La Ciudad del Saber campus (Google Maps, 2015)

According to environmental historian Dr. Guillermo Castro, the inefficiency of the Panamanian government, as well as the lack of social organization in Panama, are the main reasons for Panama's problem. The government does not give Panamanians a practical way to take care of the environment, and they also are not proactive enough to organize and stimulate governmental change. Dr. Castro stated that "if you want to create a different environment, you have to create a different society." The FCdS is beginning that process of social organization in Panama by piloting various sustainable waste disposal programs, such a recycling, that encourage community involvement and education. Composting at the CdS would another step to encourage sustainability in Panama.

A successful compost system at La Ciudad del Saber has the potential to jump-start the use of composting in Panama (Paredes, personal communication). Because of this potential, the FCdS wants to ensure that all concerns regarding a composting system are addressed before they begin composting. Concerns include vermin attraction, foul odors, and how to sell the compost. The FCdS hopes to implement a multi-step plan so they can start with a small, controlled waste flow before expansion.

2.6 Summary

The disposal of organic waste in landfills creates global problems due to high methane and toxic leachate production. Improper waste disposal can lead to various health and environmental threats such as polluting groundwater and spreading disease through contaminated water and vectors (such as insects or rodents). Composting organic waste presents a viable solution to solving these issues and many more environmental issues. In Panama, waste disposal presents a growing concern because almost all of the country's garbage goes untreated. The FCdS wants to start a pilot composting program to promote environmentally sustainable solutions to Panama's waste problem by demonstrating the feasibility of large scale composting.

3 Research Questions and Methodology

The goal of this project was to assist La Ciudad del Saber in laying the groundwork for a pilot composting program for food and vegetative waste that is technically feasible and culturally transformative.

To accomplish this goal, we pursued the following research objectives:

1. Assess compostable waste disposal practices at La Ciudad del Saber
2. Estimate the mass, volume, and composition of food and paper waste produced at La Plaza restaurant complex and vegetative waste from the CdS campus
3. Investigate cultural obstacles that could affect the success of a pilot composting program at La Ciudad del Saber
4. Investigate stakeholder (the FCdS, La Plaza restaurant complex workers, and restaurant owners) interests and knowledge gaps related to a pilot composting program

In this chapter, we detail the actions taken to fulfil the four objectives, with an emphasis on how the proposed composting program affects the stakeholders: La Fundación Ciudad del Saber, and La Plaza restaurant complex restaurant owners and employees.

Objective #1: Assess compostable waste disposal practices at La Ciudad del Saber

Desired Knowledge. In order to make recommendations for a feasible composting system, the team first needed to understand how the current waste disposal system works at the CdS. We aimed to answer the following questions about La Ciudad del Saber:

1. How are recyclables and non-recyclables disposed of?
2. How is vegetative waste disposed of?
3. What are the problems with the waste disposal system?

Method.

The team conducted interviews with the following people:

1. Ghino Robles: owner of Multiworks, the company that manages and removes vegetative waste from the CdS.
2. Alessa Stabile: Environmental Manager for the FCdS

3. Gabriel De La Iglesia: General Secretary of Panama's governmental waste authority

Justification for methodology. We needed information from sources that work directly with the waste disposal system at the CdS because they would be most knowledgeable about how the current waste disposal system works. Interviews and meetings were both efficient and effective in gathering enough information to sufficiently answer our research questions.

Limitations of method. Interviewees were invested in their various projects or company interests. Information we gathered could be skewed to protect their interests. To help mitigate this concern, data from the new vegetative waste audit and raw data from waste receipts helped verify claims and ensure reliability.

Objective #2: Estimate the mass, volume, and composition of food and paper waste produced at La Plaza restaurant complex, the Metropolitan School, and vegetative waste from the CdS campus

Desired Knowledge. To determine the volumes and weights of vegetative and food waste produced at La Ciudad del Saber, we aimed to answer the following questions about the CdS:

1. Each week, how much compostable vegetative waste is produced from leaves, grass clippings mangoes, and wood?
2. Each week, how much compostable food and paper waste is produced from La Plaza restaurant complex and the Metropolitan School?
3. What other buildings in the CdS could contribute to the composting program?

Method.

The team conducted interviews with the following people:

1. Workers at La Plaza restaurant complex
2. Ghino Robles: owner of Multiworks
3. Alessa Stabile: Environmental Manager for the FCdS

The team conducted three waste audits in the following places:

1. Food waste from various restaurants at La Plaza restaurant complex
2. Food waste from the Metropolitan School

3. Vegetative waste from the entire CdS campus

To supplement data collected in our waste audits, the team synthesized data from the following sources:

1. Receipts from Multiworks for the disposition of vegetative waste at Cerro Patacón, which contained truck weight data
2. Information from Ghino Robles about seasonal changes in vegetative waste production

To determine which buildings should be included in the study, we spoke with Alessa Stabile. Alessa provided a list of buildings to target for our waste audit and offered to contact tenants on our behalf. Based on her recommendations, we decided to focus our efforts for food waste production on La Plaza restaurant complex. While she initially did not mention sampling a school on the CdS campus, the team thought it would be useful for the FCdS to get an idea of what they produce as well as enrich our overall project. The team selected the Metropolitan School on the CdS campus for study because they would be the easiest to work with.

To quantify the mass and volume of vegetative waste, we drove around the CdS campus each day for a week to count and weigh the bags and piles of vegetative waste left out by Multiworks. Multiworks is the private landscaping company contracted by the FCdS to maintain the grounds and take the yard waste to Cerro Patacón. For bag volume, we measured average sized bags and generated an average bag volume. To calculate volume and estimate mass, the team used a tape measure to determine pile volume and took sample weights from the piles to produce an estimated weight. Through our interview with Ghino Robles, we gathered more data and parsed the two sources together to get a more accurate picture of the vegetative waste production at the CdS. In addition, we assessed the waste compositions of each vegetative waste bag labelling them as grass, leaves, sticks/wood, and palm fronds.

We gathered data from the restaurants at La Plaza restaurant complex by counting the amount of trash bags thrown away daily, weighing them, and approximating the percentage of compostable waste in each bag through visual inspection. We also asked the restaurant owners what they typically throw away and how often they take their trash out to ensure accuracy of our audit.

Lastly, we contacted personnel from the Metropolitan school in the CdS about conducting a brief waste audit at their cafeteria. We weighed sample garbage bags and visually inspected their contents to estimate the composition. We then asked the cafeteria workers on average, how many bags they think they produce in order to know what their normal production is.

Justification for method. By directly speaking to the employees of the CdS and the Multiworks manager, we were able to obtain dates, times, and locations of waste pickup to count and quantify the vegetative and organic waste disposed of each day. Our research of previous composting case studies showed that a visual inspection of waste can be enough to get a decent estimate of how much organic waste is produced. While the school waste audit was not required by the FCdS, the team felt that it would be a great way to get students involved with environmentally sustainable practices. We conducted a brief waste audit at the Metropolitan school to give the FCdS a general sense of how much larger they would need to expand their composting system if they want to expand the composting program beyond La Plaza and the vegetative waste from around the campus.

Method of analysis.

1. We calculated the total mass and approximate volumes of vegetative and food waste disposed of each week based on data from our waste audit and interviews.
2. The team determined the composition of compostable waste by volume and mass produced at La Plaza through visual inspection and taking sample bag weights on a scale.
3. To determine the percent coefficients of mass and volume by waste stream, we used a three variable system of equations. The coefficients tell us how much food waste, paper waste, and other types of organic waste contribute to the mass and volume and by how much. This is important to know in order to create a balanced blend for a compost heap.
4. We averaged the weights and volumes of sample trash bags at La Plaza restaurant complex to get an estimate of weekly waste production.
5. After interviewing Ghino Robles, we gathered more data and parsed all our sources together to get a more accurate picture of the vegetative waste production at the CdS
6. We determined the average amount and composition of compostable waste produced at the Metropolitan school by visually estimating bag composition, weighing all bags, and calculating the volume of the bin the bags took up. We then briefly spoke with the cafeteria manager to verify that what we measured was a typical day's production.

Limitations of method.

1. The team used random sampling of bags to determine an average, which is less accurate than weighing and measuring every single bag of waste produced.
2. Our research is based on a handful of volunteers and the data collected might not be representative of the whole because of normal waste production variations.
3. Because many of our interviewees were not fluent in English, the language barrier limited our understanding.
4. Multiworks sometimes puts bags of vegetative waste directly into the trucks, so the team was not able to weigh them. To address this limitation, we supplemented our data with truck weight data from Multiworks.

5. The data from Multiworks only provided mass and volume data for leaves, mangoes and palm fronds, disregarding wood and grass clippings.
6. We were unable to verify the data given to us by Multiworks. The FCdS only had a limited number of receipts from Multiworks for the disposition of vegetative waste at Cerro Patacón, and we had reason to believe that not all vegetative waste collected by Multiworks was disposed of at Cerro Patacón.

Objective #3: Investigate potential cultural obstacles that could affect the success of a pilot composting program

Desired knowledge. We identified the following research questions to help uncover any potential cultural obstacles:

1. What is the common attitude among Panamanians towards handling waste?
2. Are the majority of Panamanians willing to separate food waste from regular garbage?
3. Would most Panamanians be willing to participate in a composting program after they learned what composting is?

Method.

The team conducted interviews with the following people to gauge the common attitude towards waste management, handling, and separation:

1. Gabriel de la Iglesia: Secretary General of the Panamanian Waste Authority
2. Dr. Guillermo Castro: environmental historian
3. Sandra Icaza: community and culture specialist

To investigate potential cultural obstacles that could hinder the implementation of a composting program, the team conducted surveys (see Appendix B for our full survey) with the following people:

1. Workers at La Plaza restaurant complex
2. Shoppers at Albrook Mall, a popular megamall in Panama City

Justification for method. Getting first hand testimony from both cultural experts and Panamanians provided us with different points of view. Our diversified sources contributed immensely to understanding the average Panamanian mindset regarding waste practices.

It is important to investigate if local culture could impact the implementation of a new technology because many new technologies have failed in the past because local culture was not considered.

The survey with the workers at La Plaza restaurant complex and Albrook Mall investigated whether or not people knew what composting was, how tedious they found separating waste, and whether or not they would participate in a compost program. This survey helped the team understand how the "typical Panamanian" felt regarding separating waste and if they'd participate in a composting program. We used this data to synthesize potential cultural obstacles related to composting at the CdS.

Limitations of data.

1. Although the three experts we interviewed were fluent in English, most people at La Plaza restaurant complex and Albrook Mall were not, which made clear communication difficult sometimes.
2. It is not possible to interpret the feelings of an entire country from a few testimonies, but by diversifying our sources, we partially overcame this limitation.

Objective #4: Investigate stakeholder interests (the FCdS, La Plaza restaurant complex workers, and restaurant owners) and knowledge gaps related to a pilot composting program

Desired knowledge. To meet our objective, we sought to answer the following research questions:

1. What concerns do the La Plaza restaurant complex workers and owners have in regards to participating in a composting program? Would they be willing to participate?
2. What are the knowledge gaps (how to compost, what composting is, etc.) of the stakeholders regarding a pilot composting program?
3. What are some effective ways of bridging knowledge gaps to inform people what composting is and why it's important?

Method. To uncover interests and knowledge gaps the FCdS has in regards to composting, we interviewed:

1. Alessa Stabile - Environmental Manager
2. Tomas Paredes - Vice President of Urban Management and Development

To figure out the interests and knowledge gaps of the other stakeholders, we conducted two surveys of workers at La Plaza restaurant complex and one survey of the restaurant owners at La Plaza restaurant complex. See Appendix B and Appendix C for our survey questions. The goal of our employee surveys was to gauge their understanding about composting, if they currently partake in sustainable waste practices by separating their waste, and whether or not participating in a compost program at the CdS would impact their jobs.

Finally, the team created some sample posters to present to the FCdS as a potential method to inform workers and residents at the CdS of what composting is, what can be composted, and why it's important. We created several sample posters and conducted a brief trial at La Plaza to determine what elements in a poster people prefer to see (see Appendix G for our posters and brief survey results).

Justification for method. We needed to explore what knowledge gaps of each stakeholder has in regards to composting and sustainable waste practices to provide recommendations for how to address these knowledge gaps. We chose to pursue posters instead of other forms of educational platforms because posters are already in place at the CdS, and our research showed them to be effective and low cost.

Limitations of Method. We did not have the resources needed to create more than one type of poster that explained what can be composted, what composting is, or why composting is important. Therefore, it is possible that our sample posters may not be that effective when actually implemented. To try and mitigate this issue, we conducted a brief poster survey at La Plaza using posters we created and researched best practices in poster creation.

4 Findings and Analysis

Finding 1: Organic waste from the entire CdS campus is disposed of at the landfill Cerro Patacón, contributing to the landfill's environmental pollution, which results in health hazards.

Summary of evidence. The FCdS has two contracts to dispose of vegetative and non-vegetative organic waste from the CdS at Cerro Patacón. Multiworks collects vegetative waste, and Panama's municipal waste department (the AAUD) collects non vegetative waste. When organic waste from the CdS is dumped at Cerro Patacón, it contributes to the production of two environmental pollutants: leachate and methane. Leachate is a pollutant mixture of liquid from the decomposition of organic material, rainwater, and toxic contaminants from the landfill. Leachate from Cerro Patacón contaminates water sources including groundwater and two nearby rivers, threatening aquatic life and public health. In addition, the decomposition of organic waste in landfills produces methane, the highly flammable and powerful greenhouse gas that contributes to global climate change and fuels landfill fires.

Explanation. The FCdS, an organization dedicated to environmental sustainability, is adding to the waste problem in Panama by dumping organic waste at Cerro Patacón. The foundation is aware of this, and is looking for sustainable ways to solve the situation.

Limitations. Although Multiworks is contractually obligated to take all vegetative waste to Cerro Patacón, one official at the FCdS suspects they occasionally take waste to a private disposal site in order to avoid paying Cerro Patacón dumping fees.

Finding 2: Multiworks and the AAUD are inconsistent when they pick up trash at the CdS campus and often leave uncollected waste across campus.

Summary of evidence. Multiworks and AAUD are the two companies in charge of waste collection at the CdS. Both of these companies are not efficient when collecting the waste around the campus and are often late for trash collection. This results in the piling of trash bags at the disposal sites. Furthermore, the AAUD does not collect the trash that is not in plastic bags, causing the accumulation of trash around the disposal sites in the residential section of the CdS. Trash accumulations can be seen in Figure 9. The FCdS receives around two to five complaints a month from dissatisfied residents and tenants (Stabile, personal correspondence).

Figure 9: Uncollected waste at various disposal sites.

Explanation. The FCdS is committed to providing its tenants and residents with the best services. Uncollected waste is not only an eyesore, but it also provides food, shelter, and breeding grounds for a variety of scavengers such as rodents and insects. These organisms can carry and spread disease (Hoornweg & Bhada-Tata, 2012 p. 6).

Finding 3: The total mass and volume of compostable waste produced per week from Multiworks and at La Plaza restaurant complex are: 6.1 tonnes (43.2 m^3) during rainy season, 8.2 tonnes (88.2 m^3) during dry season, and 11.7 (64.2 m^3) tonnes during mango season.

Summary of evidence. The total compostable waste produced at La Plaza restaurant complex (food and paper waste) and collected by Multiworks (leaf and mango waste) showed us that at the absolute peak, the FCdS can expect 11.7 tonnes and 88.2 m^3 of organic waste per week.

Explanation. Our data varied within each season but the highest numbers from each season were chosen at the request of the FCdS (see the following findings and Appendix D for more information about the waste seasons and data). We included compostable waste produced at La Plaza and the vegetative waste from around the CdS campus in these totals because these are the sources of waste that the FCdS plans to incorporate in the first phase of the composting program. The FCdS wants a system that will be able to handle the absolute maximum they could reasonably expect, so that they have room to expand the program. Eventually the FCdS wants the entire campus to participate in the composting program.

Limitations. Even though palm fronds are compostable, they are tough and fibrous, so they must be shredded to be composted in a timely manner. The FCdS does not want to compost palm fronds at this time because their shredder is not equipped to handle the fibrous material. The data gathered from Multiworks groups palm fronds and leaves with branches and grass clippings, so we were not able to differentiate between them in the calculations. As a result, palm fronds are not included in the total amount of compostable waste produced and may actually include some mass from grass clippings as well. When the program expands, it is possible that the FCdS will replace the shredder and include palm fronds in the heaps. The FCdS should at that time consult the data shown in Appendix D.

Finding 4: Compostable vegetative waste production and composition vary across each of the three seasons: dry season (18 tonnes per week), rainy season (11 tonnes/week), and mango season (17 tonnes per week).

Summary of evidence. The three different seasons greatly influence vegetative waste production and composition at the CdS. See Figure 10 for weekly vegetative waste production and composition per season by mass and Figure 11 for production and composition by by volume.

Data from Multiworks:

- **Dry Season.** The dry season (December to March) produces the most vegetative waste (18 tonnes/week). Leaves and palm fronds compose half the volume of vegetative waste. Multiworks collects, on average, 14 trucks of vegetative waste per week during this season. See Appendix D Table 1 for detailed data on vegetative waste production during dry season.
- **Rainy Season.** The rainy season (April to November)[2] produces the least amount of vegetative waste (11 tonnes/week). The composition of vegetative waste by volume in this season is, as in the dry season, half leaves and half palm fronds. See Appendix D Table 2 for detailed data on vegetative waste production during rainy season.
- **Mango Season.** The mango season (June to August) produces the second most vegetative waste (17 tonnes/week). Since mango season is a subset of the rainy season, the volume of leaves and palm fronds is the same as in rainy season. Mangoes are responsible almost 6 tonnes per week. During this season, Multiworks collects 6-7 trucks of vegetative waste per week. See Appendix D Table 3 for detailed data on vegetative waste production during mango season.

[2]This report refers to the rainy season as the time from April to November that does not include the mango season in order to differentiate the two seasons.

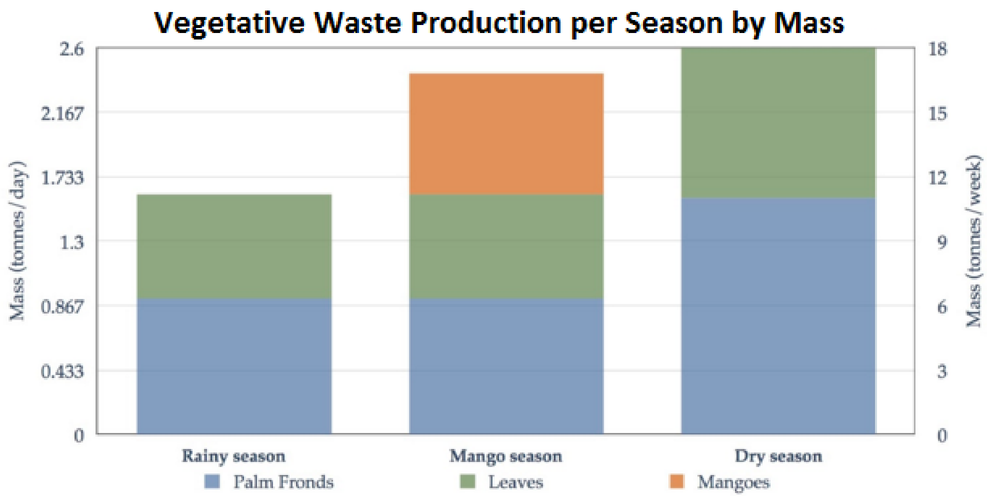

Figure 10: Weekly and Daily Vegetative Waste Production and Composition by Mass per Season at the CdS Campus

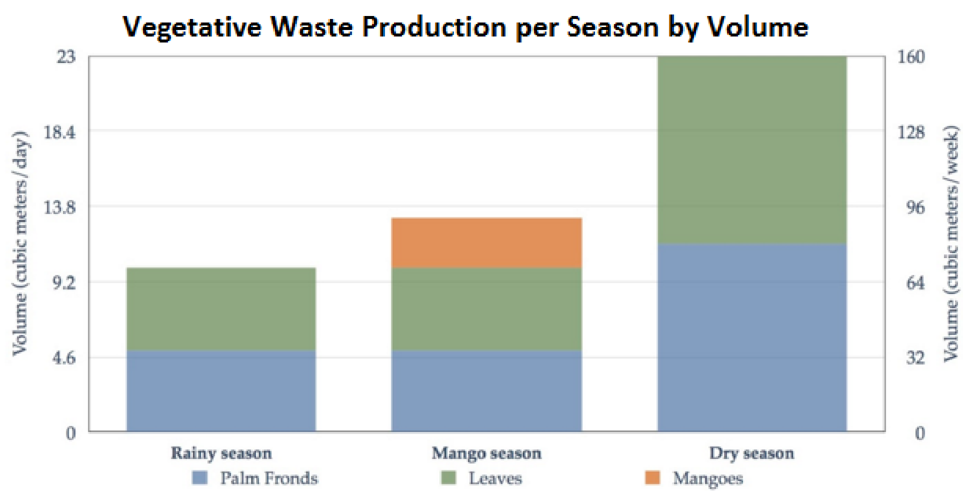

Figure 11: Weekly and Daily Vegetative Waste Production and Composition by Volume per Season at the CdS Campus

Data from our vegetative waste audit:

The team conducted the waste audit during the rainy season. During this audit, we identified and collected data for five types of waste: leaves, grass, palm fronds, logs, and sticks. We visually inspected the bags of vegetative waste around the campus to determine the composition. This breakdown of vegetative waste composition can be seen in Figure 12.

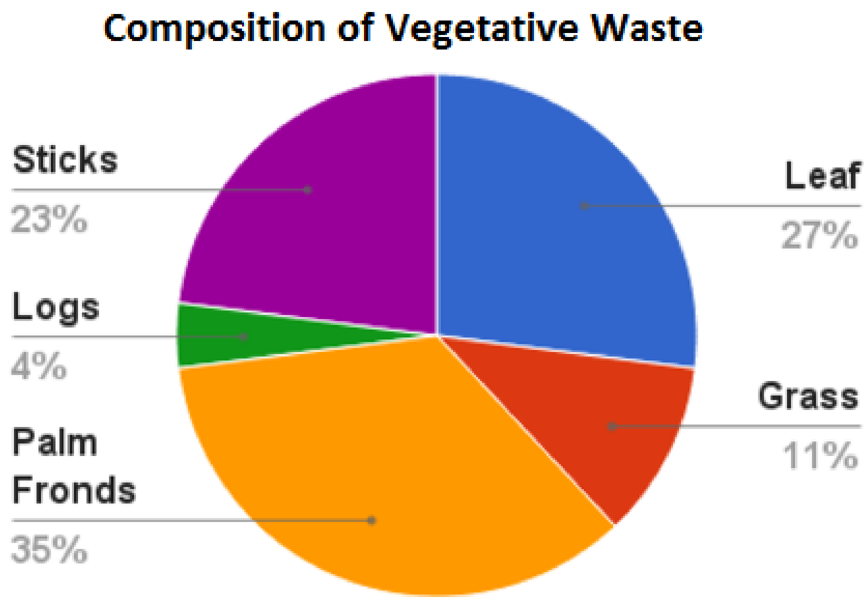

Figure 12: Rainy Season Vegetative Waste Composition by Volume

Explanation. Understanding the seasonal variations in vegetative waste production and composition is key to providing the FCdS with an accurate representation of what to expect while managing a composting system throughout the year with minimal disruptions.

According to the data from Multiworks, the percent composition of vegetative waste during the dry season and the rainy season were about the same. Increased rainfall during the rainy season compacts vegetative waste and makes it heavier. The mango season, occurring in the middle of the rainy season, has the same mass and volume of both leaves and palm fronds, with the added mass and volume of mangoes. Mangoes are quite dense, significantly adding to the weight.

This means that, throughout the year, the FCdS should expect variations in both production and composition of vegetative waste, and should plan accordingly to achieve the right carbon to nitrogen ratio in the composting pile (for more information about carbon to nitrogen ratios and the process of composting, see Appendix F). The mango season presents a significant increase in the production of green materials (nitrogen-rich). This will require the CdS to use more brown materials (carbon-rich) to balance the composting process. Also, mango seeds are non-compostable, so finished compost will require additional processing during the mango season to remove the seeds.

Limitations. The data gathered from the vegetative waste audit we conducted reports about five times less vegetative waste than the data from Multiworks. During the week we conducted the audit[3], we only observed 2 tonnes vegetative waste production at the CdS, compared to the 11 tonnes of vegetative waste per week reported by Multiworks.

[3] Audit conducted 9/9/15 through 9/16/15.

While conducting our waste audit, we observed that Multiworks will sometimes put the vegetative waste directly in the transporting trucks, as seen in Figure 13. This could explain the disparity between Multiworks data and the data from our waste audit. Another reason could be that the week we conducted our waste audit was one where Multiworks didn't collect the vegetative waste very effectively. After our vegetative waste audit, we observed that the number of vegetative waste bags around the CdS campus increased significantly.

Figure 13: Multiworks putting vegetative waste directly into their trucks

The receipts we analyzed from Cerro Patacón showed disposal weights of half the amount claimed by Multiworks. As mentioned earlier, one FCdS official suspects a possible reason for this is that Multiworks dumps the vegetative waste in an unknown location to avoid paying the dumping fee at Cerro Patacón.

The data reported from Multiworks only divides the vegetative waste collected into leaves, palm fronds, and mangoes. During the vegetative waste audit our group conducted, we found that vegetative waste produced at the CdS during the rainy season is also composed of grass clippings, wooden logs, and sticks. This makes the data from Multiworks imprecise. We relied on the data from Multiworks to calculate the production and general composition of vegetative waste per season. This imprecision limits our report in that it does not include a more detailed breakdown for the composition of vegetative waste.

Even though most of the bags of vegetative waste around the campus contained only one type of vegetative waste material, some had mixed materials. For those bags, we determined the percent composition visually. This could have led to a difference between the actual percent composition and the one we report in our vegetative waste results.

Multiworks also reported the number of full-truck trips of vegetative waste per week for each season. In our calculations, we assumed the trucks to be completely full, therefore, we multiplied the number of trips by the volume of a truckload (14 m^3). We suspect that the trucks were not completely full for every pickup; this could result in varying weekly production rates.

Finding 5: Most of the waste produced by La Plaza restaurant complex is compostable; this accounts for 95% of the mass, and 65% of the volume of the total waste produced at La Plaza restaurant complex.

Summary of evidence. Data from our week-long La Plaza restaurant complex waste audit can be seen in Figure 14 and Appendix D, Table 4. Our waste audit included both enclosed restaurants and outdoor counter-service restaurants. We found that approximately two, 0.68 m^3, bins of waste (one in the morning and one in the afternoon) were generated by the restaurant complex each day. The waste in these bins are disposed of in a compactor that the AAUD periodically takes to Cerro Patacón.

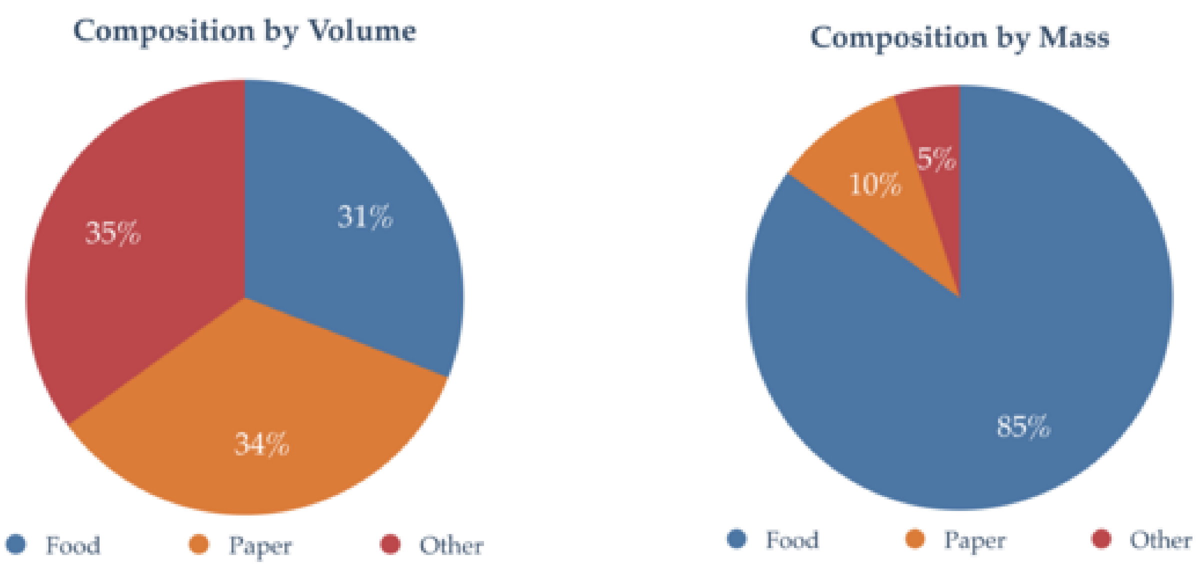

Figure 14: La Plaza Restaurant Complex Waste Composition by Volume (left) and Mass (right) Respectively[4]

Explanation. This data shows that a huge portion of waste produced at La Plaza restaurant complex is compostable. This means that the FCdS would be able to decrease the amount of waste disposed in Cerro Patacón by $\frac{2}{3}$ of the volume and almost all of the mass. Diverting organic waste from the landfill would reduce the frequency at which the compactor needs to be emptied, cutting overall waste disposal costs.

[4]Data collected from 9/10/15 to 9/16/15. The section labeled “Other” includes mostly non-recyclable plastic with small amounts of both recyclable plastic and metal cans.

Our data shows nearly $\frac{2}{3}$ of the volume of the waste produced at La Plaza restaurant complex can be composted. To generate the data shown in Figure 14 (and eventually Figure 15), the team used a three variable system of equations to determine how much of the mass and volume each waste stream occupies. As it was already expected, the mass of the food waste was much larger than the mass of paper and plastic; even though they all have nearly the same percent compositions of volume. In fact, food waste accounted for nearly 95% of the mass of the waste produced, making it far heavier than plastic and paper products.

Finding 6: Most of the waste produced at the Metropolitan (MET) school is compostable; this accounts for 95% of the mass, and 70% of the volume of the total waste produced at the MET School.

Summary of evidence. Similar to the results from the La Plaza restaurant complex audit, this data shows that a huge portion of the waste produced at the MET school is compostable. Data from our small-scale school waste audit is represented in Figure 15 and Appendix D Table 5. According to the cafeteria manager, waste production at the school is consistent throughout the whole school year, excluding the months they have vacation (June-August). We found that the MET school produces almost a full bin of waste (nearly 1 m^3) each day.

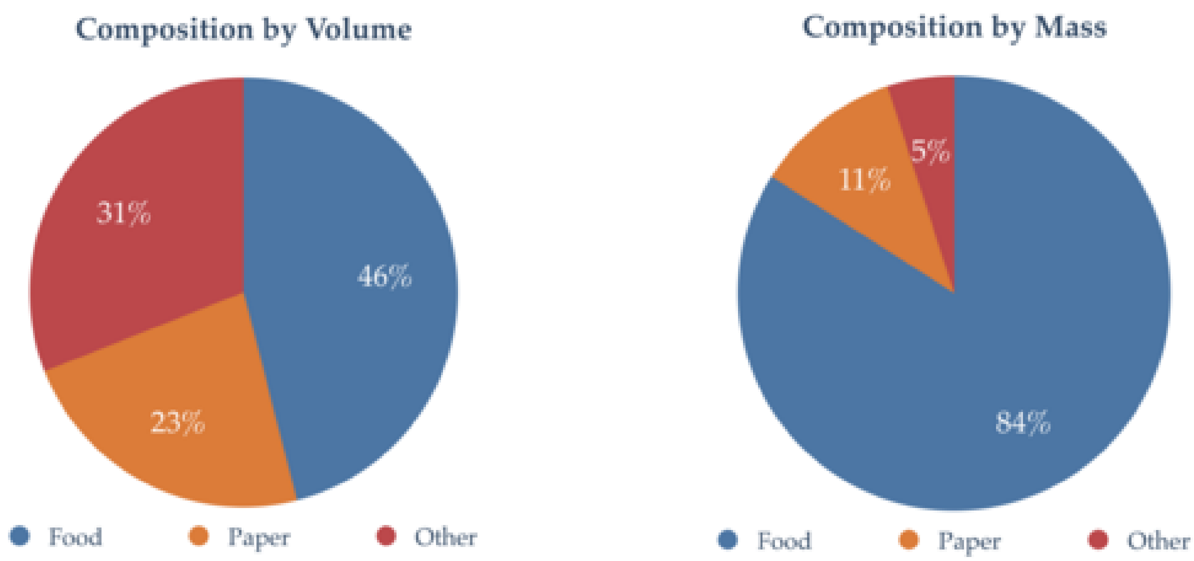

Figure 15: Metropolitan School Waste Composition by Volume (left) and Mass (right) Respectively[5]

Explanation. We decided to audit the Metropolitan School's cafeteria because this school would be a good starting place for the expansion of the pilot composting program. While it will not be in the initial pilot compost phase, we wanted to see how it's

[5]The section labeled "Other" includes mostly non-recyclable plastic with small amounts of both recyclable plastic and metal cans.

waste production compared with the production from La Plaza restaurant complex (see Recommendation 5 for more information).

Finding 7: While most Panamanians understand that Panama faces growing waste challenges, their limited knowledge of sustainable practices and cultural habits regarding waste disposal, prevent them from separating their waste.

Summary of evidence. Sandra Icaza, a community and culture specialist, claimed that "common, everyday Panamanians don't know about sustainable practices." Data from our survey supports this claim, as eighteen out of twenty of the people we surveyed did not know what composting was. Icaza also stated that Panamanians are willing to learn about sustainable practices if the government will support them, saying that Panamanian culture can be changed once they are taught how to help the environment. This became evident in our survey, when all of the 20 Panamanians interviewed agreed that they would participate in a composting program if the government instituted it.

At La Ciudad del Saber campus, only one fifth of the materials placed in the recycle bins can be recycled (Stabile, personal correspondence). This is because people put non-recyclable materials in the recycle bins. Recyclables are also thrown in the trash bins as seen in Figure 16. This is an example of people in Panama not separating their waste, even if they are given the means to do so, because they are not educated on recycling practices.

Figure 16: Recyclables in the Trash at La Ciudad del Saber

Explanation. Even though more than half of the typical Panamanians surveyed said that separating waste in their homes is easy, most waste is unseparated at disposal. See Figure 17 for responses. Currently, no government-funded recycling programs exist. Dr. Castro, an environmental historian, claims that Panamanians are very reliant on the government because they have poor social organization, which prevents them from rallying as a group to spur change. This suggests that with governmental support, Panamanians could make the change and participate in recycling programs. A government-funded educational program could change the culture of waste disposal in Panama (Icaza, personal correspondence).

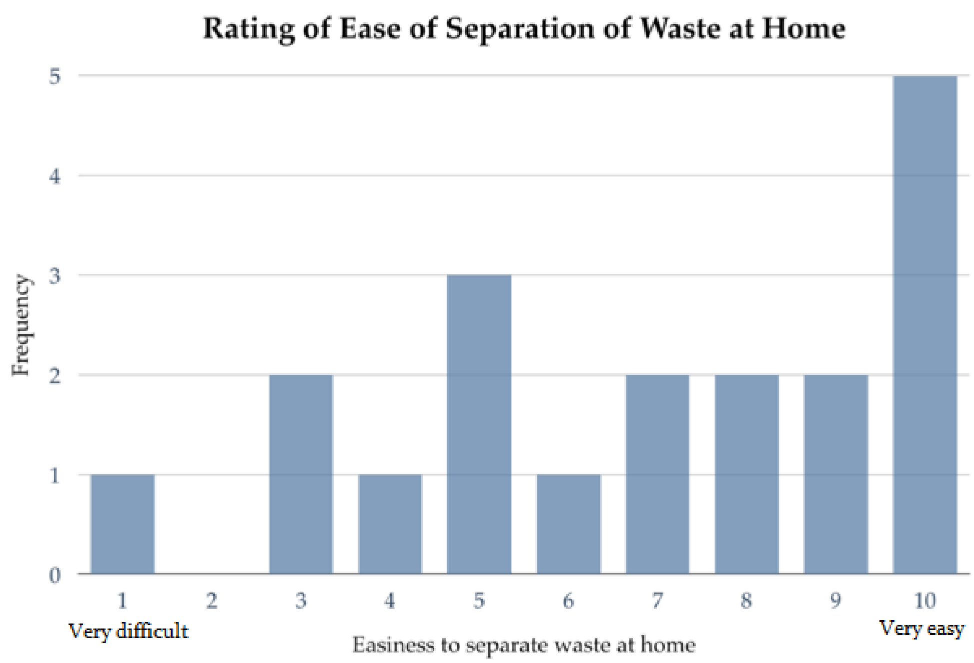

Figure 17: Rating ease of waste separation by people in Albrook Mall and La Plaza Restaurant Complex

Limitations. Even though we tried to be as unbiased as possible while conducting the survey, we noticed that people could feel inclined to say they would participate in a composting program, once they learned what composting was (see Appendix B). Tomás Paredes, Vice President for Urban Management and Development for the FCdS, confirmed this limitation, claiming that, culturally, many Panamanians will agree to something before learning all of the details or thinking through all of the implications. To partially address this, we emphasized the optionality of the program.

Finding 8: Most of the restaurant owners (80%) at La Plaza restaurant complex believed that separating their waste would not affect their business and all restaurant workers felt separating waste would not place a significant burden on their jobs.

Summary of evidence. We asked five tenants at La Plaza restaurant complex whether the separation of waste for a composting program would affect their business. Four said that separation would not affect their business. One tenant even said that the implementation of separating practices would be beneficial because it would be easier for her to take out the trash. One restaurant owner said that separating waste would take too much time and that it would affect his business.

We also asked restaurant employees whether the separation of waste would negatively affect their jobs. Their responses were also favorable. All the 10 employees surveyed replied that it would not negatively affect their jobs in anyway. Three employees said that while they believe that this new practice would make their tasks take longer, they would not have a problem doing it.

Explanation. Since the FCdS is planning on getting all of its food waste for the initial phase of the composting program from La Plaza restaurant complex, it is important that the tenants are willing to participate in the waste separation. These favorable responses indicate that the FCdS will have the support from most of the restaurant owners and employees of La Plaza restaurant complex.

Limitations. We only interviewed approximately $\frac{1}{4}$ of restaurant owners in La Plaza restaurant complex, so it was not possible to fully represent the attitudes of the whole based on the small sample size. It is also not entirely possible to assume that the restaurant owners and employees will actually participate in the waste separation, even though they do not think it will be a detrimental task.

5 Conclusions and Recommendations

Conclusions:

Objective 1: Assess waste disposal practices at La Ciudad del Saber.

Finding 1: Organic waste from the entire CdS campus is disposed of at the landfill Cerro Patacón, contributing to the landfill's environmental pollution, which results in health hazards.

Finding 2: Multiworks and the AAUD are inconsistent when they pick up trash at the CdS campus and often leave uncollected waste across campus.

Objective 2: Estimate the amount of food waste produced at La Plaza restaurant complex and compostable vegetative waste produced at the CdS campus

Finding 3: The total mass and volume of compostable waste produced per week from Multiworks and at La Plaza restaurant complex are: 6.1 tonnes (43.2 m^3) during rainy season, 8.2 tonnes (88.2 m^3) during dry season, and 11.7 (64.2 m^3) tonnes during mango season.

Finding 4: Compostable vegetative waste production and composition vary across each of the three seasons: dry season (18 tonnes per week), rainy season (11 tonnes/week), and mango season (17 tonnes per week).

Finding 5: Most of the waste produced by La Plaza restaurant complex is compostable; this accounts for 95% of the mass, and 65% of the volume of the total waste produced at La Plaza restaurant complex.

Finding 6: Most of the waste produced at the Metropolitan (MET) school is compostable; this accounts for 95% of the mass, and 70% of the volume of the total waste produced at the MET School.

Objective 3: Investigate potential cultural obstacles that could affect the success of the program.

Finding 7: While most Panamanians understand that Panama faces growing waste challenges, their limited knowledge of sustainable practices and cultural habits regarding waste disposal prevent them from separating their waste.

Objective 4: Identify stakeholder concerns and knowledge gaps

Finding 8: Most of the restaurant owners (80%) at La Plaza restaurant complex believed that separating their waste would not affect their business and all restaurant workers felt separating waste would not place a significant burden on their jobs.

Recommendations for La Fundación Ciudad del Saber

1. To ensure high levels of participation, we recommend informing people who live and work at the CdS about the new composting system by implementing a poster campaign around campus, emailing residents and businesses, and posting information about composting on social media sites.

High participation is critical to a successful composting program. From our literature review, we found that when municipalities educated people on what composting is and why it's important, more people participated. Posters are one effective way for large scale promotion and education. We recommend that posters be displayed in a variety of locations and platforms to engage as many people as possible to participate. In order to provide a better poster recommendation, we conducted a brief poster survey. About 75% of participants preferred Poster 1 in Appendix E (see Appendix E for the recommended sample posters and Appendix F for survey results). We therefore recommend that the FCdS consider implementing a poster similar to Poster 1. Participants in the survey said that the poster was attractive and that they would read the text on the poster. We explored other composting poster designs in our research and drew design elements from the posters we felt were the most effective at explaining what materials are compostable.

In addition to displaying posters near waste bins around campus, we also recommend the FCdS send out educational emails to all businesses, tenants, and workers at the CdS campus, informing them of what composting is and why the FCdS is launching a composting campaign. These emails should contain simple, yet effective messages about what composting is and why people should participate. Content could include educating residents on how organic waste in Cerro Patacón fueled the landfill fire in 2013 and how landfilling organic waste poses a direct threat to their health. Lastly, we recommend posting this information on social media websites because many people use these sites in their daily lives. This will enable the FCdS to reach more people than simply displaying posters around campus or through emails.

2. To minimize the personnel needed to maintain the compost program, waste should be sorted when it is thrown away and the organic waste should be placed in a semi-automated composting system.

Maintaining a compost system can be expensive because of labor cost. To minimize the burden on existing maintenance personnel, the system should include measures for minimal processing. When waste is thrown out, it should be separated by those throwing it out because separating mixed trash is very time consuming and labor intensive. This can be accomplished by providing organics-only trash bins in La Plaza restaurant complex and residences. If people separate their trash as they throw it away, organics can just be dumped directly into the compost heap. However, workers should quickly inspect the compost bins to make sure no inorganic material was accidentally disposed of in those bins.

The FCdS wants to purchase the Pila de Aireción Mixta composting units from EARTHGreen Colombia. These self-sustaining systems are capable of handling 2-200 tonnes of waste per day for 25-day compost cycles. While this type of system only regulates oxygen, and temperature to a minor degree, the capital costs are much lower than fully automated machines with almost as little maintenance. We therefore recommend the FCdS continue pursuing these types of semi-automated machines as they would likely be the most cost effective type for the FCdS. The semi-automated system eliminates the need for employees to turn the pile, which can be laborious and time consuming. Once the compost pile has been assembled, workers only need to check temperature and moisture in the pile periodically.

3. To be prepared for the maximum amount of waste, the FCdS should develop a system capable of storing and composting approximately 11.7 tonnes ($88.2m^3$) of organic waste per week.

At absolute most, compostable waste from La Plaza and vegetative waste from around campus would amount to 11.7 tonnes of organic waste per week. We recommend the CdS initially buy a system that can handle 11.7 tonnes of raw material per week (1.7 tonnes per day) with an expected initial volume of $88.2m^3$. The 11.7 tonnes per week estimate is a high estimate because the FCdS asked the team to calculate high so they can purchase a system with capacity to expand and handle waste fluctuations. It is better to purchase a larger than necessary system so that the FCdS will be able to handle days of abnormally large organic waste as well as be able to expand their system to include more buildings and households.

4. To minimize any negative impacts the compost heaps could have on those who work and live at the CdS, the compost system should not be located near highly populated areas.

One of the main concerns of the FCdS is the potential negative impact a compost system could have on residents of the CdS campus. The FCdS is concerned about foul odors being emitted from the piles and thereby attracting vermin. These concerns can be mitigated by purchasing a semi-closed composting system, topping the compost heaps with sawdust or soil, and placing the system far from populated areas. A good location for this compost system is the previous Fort Clayton shooting range, which is up a hill in the back of the campus. A plant nursery currently resides here, making this location even more ideal for composting because the compost can be used to supplement the plant growth. In addition, the location is far away from residential and commercial areas, and should not create any problems for residents or businesses.

Although concerns about foul odors from compost heaps exist, composting does not actually smell if processed properly. A compost pile will only produce foul smells if the pile mixture contains too much nitrogen. Nitrogen-rich materials, such as food and green vegetation (excluding most leaves though), are referred to as "green" materials. To eliminate odors, we recommend the FCdS mix carbon-rich materials, or "brown" materials, such as dry leaves and wood chips, into compost piles. For more detail on green and brown materials, see Appendix G.

Finding the optimal ratio of brown to green using organic waste for the FCdS may take a few trials. Generally, the recipe for composting includes many small, alternating layers of green material and brown material, with the largest layer of brown materials at the bottom (see Appendix G for more information on how to layer compost piles). We recommend the FCdS cover the tops of compost heaps with soil or sawdust to both help block smell from leaving the pile and supply useful microorganisms to assist in pile decomposition. Because shredded materials compost faster, we recommend the FCdS shred vegetative waste before throwing into compost piles. Finally, we recommend experimenting with different brown to green ratios to uncover an ideal composting recipe for the CdS.

5. To expand the composting program to include all CdS buildings, we recommend a gradual three phase rollout to ensure quality control and allow time to form partnerships.

Phase 1: Implementation. This initial phase will only include compostable vegetative waste from around the CdS and food and paper waste from La Plaza restaurant complex. These two sources are the easiest for the FCdS to work with because they have contracts with them and they would be easiest to transport. During the implementation phase, any unforeseen challenges that occur will be able to be addressed by the FCdS before more of the CdS is included in the composting program.

In this stage, we recommend the taking of weekly samples from the first compost piles to determine how long the compost piles should decompose. When compost reaches its ideal stage, the pile stops shrinking and the compost texture is similar to that of soil. If compost piles compost for too long or are too dry, the center of the pile could char and produce foul odors. Therefore, it is critical the FCdS monitor the compost pile periodically to determine if the pile needs more water. We also recommend that the FCdS use a temperature probe to verify the center of the pile is reaching around 60C (140F) after three to five days of decomposition. This temperature is ideal for decomposition and the destruction of any harmful pathogens that may be present.

We also recommend the FCdS explore potential avenues for selling their excess compost to local farmers and community growers during this phase. The FCdS will likely not need to sell compost during this phase because many areas around the CdS could use a lot of compost, but it is important to begin exploring options so they have the connections in place (see background section 2.4 for reasons why). In addition, any technical issues with the quality of compost or logistics of transporting material will be able to be ironed out during this phase. Once this phase is complete and the composting system produces the quality of compost the FCdS is looking for, we recommend the FCdS proceeds to phase two.

Phase 2: Expansion. We recommend the FCdS include food and paper waste from the schools at the CdS, organic waste from a local Chinese market the FCdS currently has connections with, as well as pursue connections made with local farmers earlier in phase one. We recommend that the FCdS network with local growers during the farmer's market the CdS holds periodically. This will be an easy way to network with local growers. There also may be individuals who would want to buy small bags of compost to use as fertilizer for their own gardens or flowerbeds. The FCdS will likely need to start selling their compost during this phase because production is increasing and the need for fertilizer around the CdS campus is decreasing.

During the expansion phase, there will be a larger source of food waste available to compost with the addition of the schools and the Chinese market. Our data from just the Metropolitan School (one of three schools on the campus), showed that they produced nearly as much as La Plaza. This means the FCdS will have to rebalance their compost heaps to accommodate the increased green material source.

Phase 3: Partnership. During this final phase, the FCdS should incorporate all buildings on the CdS campus into their composting program, such as the Holiday Inn and private residences. At this point, we recommend the FCdS explore commercial ventures for their compost. It is possible that the FCdS could sell their compost as a commercial product for nearby garden stores and farmers in order to turn their composting system into an economically sustainable system. After this phase is complete, the CdS will demonstrate to the rest of Panama that composting presents a sustainable and viable solution to Panama's waste crisis.

Recommendations for Future Projects

1. To assist the FCdS in expanding the compost system, we recommend a waste audit of the residential section of the CdS and a business plan for selling the compost.

Conducting a residential audit will help the FCdS learn about the waste habits of their tenants and will provide them with the information they need to expand the compost system. During this audit, we also recommend a survey of the residents to learn about their interests and concerns for the program.

The FCdS is interested in eventually selling finished compost to local farmers and community growers. This requires careful planning in the form of a business plan. This plan can include measures for marketing, distributing, and selling the compost.

2. To uncover the social problems associated with waste management in Panama, we recommend a study of the communities most affected by the waste crisis.

The waste crisis in Panama affects many low-income communities in and around Panama City. We recommend a study of these communities to provide the government with recommendations on how to help the people living in poor conditions.

Project Design Principles

In our research for La Ciudad del Saber, we discovered certain practices that helped us address the social and technological complexity of our project.

1. Social considerations must be made when implementing new technologies.

New technology is often implemented in foreign countries without regard to local culture. This disregard usually leads to unsuccessful implementation. Because a compost program requires local participation, the program must be tailored to the people's needs. It was important for us to consider Panamanian knowledge and opinions regarding composting to design a successful composting system. For example, we discovered that most Plaza workers at La Ciudad del Saber did not know what composting was. They would be the ones that would need to separate the waste.

2. Connections with influential and well-connected people are sometimes necessary to get in contact with possible interviewees.

Many of our interviews were only possible because of the connections we made through La Ciudad del Saber. Having a well-known contact facilitate interactions with potential interviewees validated our credibility and increased our chances of receiving a response. Alessa Stabile, the head of environmental management, and Dr. Castro, the Vice President for Research and Education at La Ciudad del Saber both provided us with contact information and facilitated interactions with interviewees when we were unable to land interviews ourselves. This strategy both limits and expands our interview horizons. Using the sponsor's contacts could limit the team to interviewees with the same point of view as the sponsor. On the other hand, many people would not respond to us students, so the sponsors' contacts were helpful in getting us interviews.

3. A variety of parties should be consulted to uncover the full complexity of the project

In our research we needed to interview not only La Fundación La Ciudad del Saber, the main stakeholder, but also the people at La Ciudad del Saber affected by the implementation of a compost system. We found it helpful to survey these people as well as experts in the field to design the best advertising campaign.

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A The Science of Composting

In order to provide recommendations to La Fundacion Ciudad del Saber for ideal composting, it is important to first understand how composting works. This knowledge may directly impact our recommendations for a successful composting system that can transform organic waste into nutrient rich humus. We have outlined five elements needed to create nutrient rich compost.

1. A balance of green and brown materials. Feedstock and nutrient balance refers to the ratio of carbon to nitrogen in the compost (Maine Department of Environmental Protection, 2013). This means that a variety of different "brown" and "green" materials must be present in order for proper decomposition to occur. Brown materials are rich in carbon and slow to decompose; examples include wood chips, dry leaves, and tree branches. Green materials include grass clippings, food scraps, and manure; they are nitrogen rich and fast to decompose. The ideal ratio of green to brown materials is 30:1 (University of Florida, 2011).

2. Organisms break down materials. In a compost heap, various macro and microorganisms break down biodegradable compounds. These organisms accelerate the decomposition process. Macroorganisms, such as centipedes, sow bugs, snails, millipedes, and ants, grind the larger materials into smaller pieces to give the bacteria more surface area to decompose. Aerobic bacteria play the most important role in decomposition. These bacteria utilize carbon, as a source of energy; nitrogen, to produce protein that will aid in replication; and oxygen for respiration (Trautmann & Krany, 1997).

3. Aeration for oxygenation and temperature control. The heat produced during decomposition causes the compost pile's temperature to rise. When the temperature exceeds 40°C (104°F), proteins, fats, and other complex carbohydrates breakdown. The temperatures can be controlled during composting by mixing the organic materials. This replenishes the oxygen supply at the center of the pile and brings new material to the center for optimal composting conditions (Trautmann & Krany, 1997). This can be controlled with an aerated, automatic composting system. If the temperature at the center of the pile gets too high or if oxygen levels fall below 5%, anaerobic microbes will grow. This prevents decomposition into humus, causing the material to rot, which produces foul-smelling methane (Trautmann, 1996).

4. Moisture level. Moisture content is very important to the overall quality of the composting process. A moisture content ranging from 40%-60% is considered optimal (Cornell Waste Management Institute, 1996 a). Bacteria need moisture to travel in a compost pile, but too much moisture suffocates them. Suffocation allows anaerobic processes to occur, which causes the pile to rot, producing foul odors and slowing the composting process. Usually nitrogen rich materials are very moist, while carbon rich materials are dry. (University of Florida, 2011).

5. Particle Size. In compost heaps, smaller particles decompose faster than larger particles. This is because smaller particles, such as shredded materials, have more surface area for the microorganisms feed on. In solid, dry pieces of wood, it is difficult for oxygen and microbes to reach the core, drastically increasing decomposition time. This makes the shredding or grinding of wood pieces especially necessary. On the other hand, grinding greens will compact the compost. A compacted compost prohibits the flow of oxygen and moisture between particles, slowing the composting process (Trautmann & Krany, 1997).

B Survey - How do Panamanians Feel about Composting?

1. On a scale of 1 to 10, how easy is it to separate garbage in your home? 1 is very hard and 10 is very easy.

2. Do you know what composting is?

   Composting is the process of converting organic garbage, such as yard waste and food waste, into a nutrient rich soil.

3. If there was an optional government program for composting, would you participate?

C Survey- How Would a Composting Program Affect You or Your Business?

To La Plaza restaurant owners/managers:

1. How would separating your organic waste affect your business?

To La Plaza restaurant workers:

1. How would separating organic waste affect your job?

D Waste Audit Data

Material	Volume (m^3/day)	Volume (m^3/week)	Mass (tonnes/day)	Mass (tonnes/week)
Leaves	11.5	80	1	7
Palm Fronds	11.5	80	1.6	11
Total	23 m^3/day	160 m^3/week	2.6 tonnes/day	18 tonnes/week

Table 1: Dry season vegetative waste production data from Multiworks

	Volume (m^3/day)	Volume (m^3/week)	Mass (tonnes/day)	Mass (tonnes/week)
Leaves	5	35	0.7	4.9
Palm Fronds	5	35	0.9	6.3
Total	10 m^3/day	70 m^3/week	1.6 tonnes/day	11 tonnes/week

Table 2: Rainy Season Vegetative Waste Production data from Multiworks

	Volume (m^3/day)	Volume (m^3/week)	Mass (tonnes/day)	Mass Rate (tonnes/week)
Mangoes	3	21	0.8	5.6
Leaves	5	35	0.7	4.9
Palm Fronds	5	35	0.9	6.3
Total	13 m^3/day	91 m^3/week	2.4 tonnes/day	17 tonnes/week

Table 3: Mango season vegetative waste production data from Multiworks

	Volume (m^3/day)	Volume (m^3/week)	Mass (tonnes/day)	Mass Rate (tonnes/week)
Food	0.65	3.9	0.18	1.1
Paper	0.71	4.3	0.02	0.13
Total	1.3 m^3/day	8.2 m^3/week	0.2 tonnes/day	1.2 tonnes/week

Table 4: La Plaza Restaurant Complex Organic Waste Production

	Volume (m^3/day)	Volume (m^3/week)	Mass (tonnes/day)	Mass Rate (tonnes/week)
Food	0.34	1.7	0.16	0.8
Paper	0.17	0.85	0.02	0.1
Total	0.51 m^3/day	2.6 m^3/week	0.18 tonnes/day	0.9 tonnes/week

Table 5: Metropolitan School Organic Waste Production

E Sample Posters

Poster 1: What can be Composted?

Poster 2: The Composting Cycle

F Survey- Sample Posters

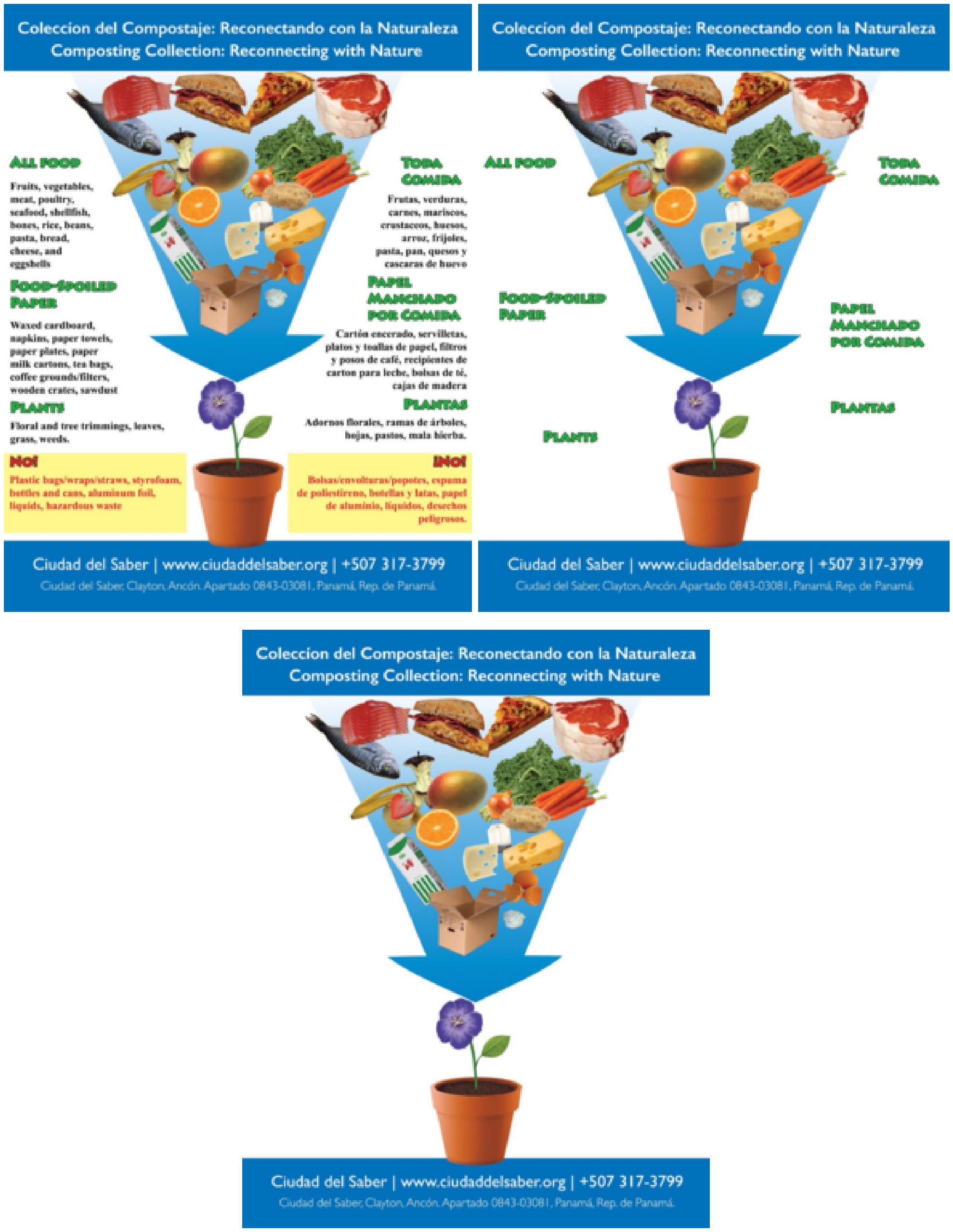

Figure 1: Various Posters Included in the Trial

We showed these three posters to 20 participants at La Plaza in our survey. We asked the participants which of the three posters they felt was most "readable" and was also effective in teaching them what materials can be composted. 15/20 participants preferred the poster on the top-left and 5/20 preferred the poster top-right. When participants chose the poster on the top-left, we asked if they would actually read the text if they saw it displayed at La Plaza restaurant complex. All participants said that they found the poster appealing and said they would read the text. Using these results, we made the recommendation to use the poster shown in Appendix E.

G Green and Brown Materials: More About the C:N Ratio

"A C/N [carbon to nitrogen ratio] of 30:1 will permit digestion to proceed at the highest possible rate. But the nitrogen and carbon content of plant and animal waste changes greatly, depending on the type, age, and growing conditions of the plant, and the kind, age, diet, and degree of confinement of the animal.... The composting of plants is another factor that changes the C/N ratios; it lowers them. . . . One week of Composting can bring a plant waste with a C/N of 100 down to a C/N of 20" (Arnott, 1985).

For more information about what materials are considered "green" or "brown," please see Figure 1 below.

Recommended Wet or Green Scraps (nitrogen-rich)	Recommended Dry or Brown Scraps (carbon-rich)
∘ Fruits ∘ Vegetables ∘ Old flowers ∘ Dead plants ∘ Young weeds ∘ Manure from herbivores ∘ Tea bags ∘ Coffee grounds ∘ Leaves (if moist) ∘ Pond algae and seaweed (sparingly) ∘ Grass cuttings (if the lawn is not treated with chemicals)	∘ Dry leaves ∘ Black and white newspaper ∘ Dry hedge clippings ∘ Dry garden trimmings ∘ Paper towels (do not use ones that were in contact with meat) ∘ Straw or hay ∘ Small wood chippings (if not treated with chemicals) ∘ Crushed egg shells ∘ Tissues ∘ Cardboard (if untreated) ∘ Coffee filters ∘ Ashes (from plants/wood) ∘ Old clothes or fabric made from natural fibers ∘ Sphagnum peat moss ∘ Coconut husk fibers (coir)

Figure 1: Green and Brown Materials (Science Buddies Staff, 2014)

Compost heaps should be layered in a similar fashion to figure 1 shown below. The middle layer does not need soil if there are no test items being composted in the heap. "Test items" could include meat or chicken bones.

Figure 2:Layering Green and Brown Materials (Science Buddies Staff, 2014)

For more information on green/brown materials or the layering of compost heaps, please visit `http://www.sciencebuddies.org/science-fair-projects/project_ideas/EnvSci_p058.shtml`