Rainwater Harvesting in Matènwa, Haiti

An Interactive Qualifying Project

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Abstract

The purpose of this Interactive Qualifying Project is to propose a practical, short-term solution to the water scarcity faced by the citizens of Matenwa, a mountainous village of La Gonave, Haiti. This report details our research concerning the selection of an appropriate rainwater harvesting method to solve the water shortage problem, a plan for physically implementing and maintaining this system, and ways to cultivate community participation in this implementation.

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Executive Summary

Countries with abundant precipitation have an opportunity to collect and use rainwater for vital human purposes, including drinking water and plant irrigation. Lacking infrastructure and financial resources, developing countries that are facing water scarcity, can use rainwater collection to address problems created by the scarcity. The Indian Government is a pioneer in utilizing the rooftop harvesting system to provide reliable sources of water for daily use and has successfully launched rooftop programs for 23,638 schools. Some of these methods can be successfully applied to similar scarcity problems in Haiti.

The small mountainous village of Matènwa, located on the island of La Gonâve, Haiti, is a community facing water scarcity problems. Women have to walk for several hours every day to fetch water for daily use. Nevertheless the water they collect for drinking and cooking carries germs for Chronic Diarrhea, Hepatitis and Cholera, which put their lives in danger. An extensive deforestation problem has contributed to the pollution of water sources, further complicating Haiti's thirst for potable water.

In order to alleviate water scarcity and provide more clean water for the village of Matènwa, four students from Worcester Polytechnic Institute teamed up to find the most effective way of supplying drinkable water for this rural village without adequate resources. Our research shows that rooftop rainwater harvesting is their best option. This report explains how we reached this conclusion after considering the current water scarcity problem in Matènwa, particularly issues relating to environmental damage due to deforestation. To determine an appropriate solution that would be accepted and implemented by the people of

Matènwa, we took into consideration socio-economic factors as well as traditional cultural practices in Haiti.

The water harvesting system mainly consists of four parts: a rooftop collection area, a conveyance system, storage facilities, and a purification device. The rooftop collection area generally refers to the surface, in this case the roof of houses that bear rainwater flows. This component has to be designed with sufficient inclination and strength in order to stand peak flow and avoid standing water. The rainwater then goes through a conveyance system that is designed to transfer water caught on a rooftop to the storage facility by using pipes and gutters that many families in Haiti have already built on their houses. We note research carried out by another WPI team of students that suggests that the cost of pipes and gutters can be reduced by using bamboo, which grows naturally on the island of La Gonâve. However, we reject this solution because bamboo requires too long a growth time, decays too rapidly, and can be easily attacked by termites and bacteria. The storage facility should use underground cisterns because of their price advantages as well as their strength to prevent water loss. Water that is to be used for drinking will be filtered through a purification device to meet sanitary human standards. We chose ceramic filters as the purification device because of their relatively low price, high effectiveness, and ease of maintenance.

In deciding how to best implement the building of a rainwater harvesting system, we took into consideration the culture and society of small Haitian villages. Our goal was to involve the entire community in fitting houses with rainwater collection devices. We recommend that any agency helping Matènwa with this project use a community empowerment method, such as Participatory Rural Appraisal (PRA), to mobilize all members of the village to participate in the project. The first step in this development strategy is to establish a water-collection leadership team that will establish the resources available to carry out the project and organize tasks that need to be carried out. This report shows how the use of PRA can empower the community by giving them ownership over the project and its outcome, by engaging them in a process of determining a solution to the problem of water scarcity, and by having them access, plan, monitor, and evaluate their own solutions. PRA goes beyond simply helping the citizens of Matènwa solve this fundamental problem of the lack of clean drinking water, it gives them a collective method to tackle other obstacles blocking their future development.

Introduction

Water scarcity is a problem for many developing countries including Haiti. According to the Food and Agriculture Organization of the United Nations, 33% of Haiti's population (nearly 3 million people) has no access to potable water. Matènwa is a village located on the Haitian island of La Gonâve, west from Port-au-Prince and, as many other remote villages, it is faced with water shortage that is mainly caused by the soil's inability to retain rainwater due to deforestation. The purpose of this Interactive Qualifying Project (IQP) is to propose new ways to collect water for the community of Matènwa, Haiti. This project is being sponsored by Zanmite, a charitable organization based in Cape Cod, Massachusetts, that supports Haitian artists through an artistic development program (see Figure 1).

Figure 1 – Matènwa Haitian artist (Picture courtesy of Artmatenwa.org)

With the support of Wellfleet and The Mangrove Fund, Zanmite built a community center that assists the Matènwa Haitians in selling hand-made art works and encourages selfrespect and independence among women without exhausting their limited resources. Since the majority of the artists in the community center are women and they often have to travel several miles to get water for their household, their time to work in the artistic center is restricted and their production decreases. At the same time, the lack of a source for clean water in the village also compromises the children's education because they have to commit their time to household chores involving water collection.

Engineers and development experts have established many ways of collecting rainwater, such as roof water collection and land surface catchment that we will discuss in the pages below. Because of Matènwa's extensive poverty, this report will consider the many benefits in establishing an inexpensive roof water harvesting system, explain how such a system can be constructed, and determine the appropriate filtration and storage system for collected rainwater, while seeking the least costly means to collect and purify water. This report will explore the use of ceramic filters as a way for villagers to purify rainwater for drinking purposes.

Figure 2 – Matènwa Haitians working the land (Picture courtesy of Artmatenwa.org)

The underdeveloped condition of the island of La Gonâve, makes transportation to Matènwa very difficult and uncomfortable; the trip from the port city of Anse-à-Galets to Matènwa is approximately two hours long, and people usually get there riding on the back of a pick-up truck through the narrow unpaved roads. Houses in Matènwa are very small and often accommodate families of up to 12 members. As shown in Figure 2, villagers in Matènwa live almost entirely by subsistence farming using simple hoes and shovels and have only the most limited commercial activities. Therefore, some outside funding will probably be needed even with the use of the cheapest methods of constructing a roof-top harvesting system.

In Haiti, many inhabitants in remote areas are still using traditional and inefficient means to collect water, in part because most charitable organizations that might find better solutions to the problem are usually located around the bigger cities. In Matènwa, as throughout the developing world, it is the cultural practice of villagers that women and children collect water. This necessity often keeps women from other commercial activities and children out of school. In order to change this age old practice, and to mobilize the village toward improved living conditions, those who seek to help people in Matènwa by empowering the community must understand Haitian social and cultural practices so that any proposed solution will be sensitive to traditional Haitian customs and values. We will discuss some of Haiti's common socio-cultural characteristics in the pages that follow.

In Haiti, 94% of the water is used for agricultural purposes, 5% for domestic purposes, and 1% for industrial purposes (as reported by the World Resources Institute), but nearly every water source in Haiti has become highly contaminated with human waste due to the lack of sewage purification systems. In consequence, germs of cholera, chronic diarrhea and hepatitis are ubiquitous in the drinking water, contributing to the highest infant mortality rate in the Western Hemisphere according to International Action (63.7 per 1000 live birth in 2008 – World Bank, World Development Indicators). It is also reported by the Pan-American Health Organization (PAHO) that more than half of all Haitians die of intestinal infections caused by germs carried in the water.

In addition, Haiti is the poorest country in the Americas, and with the average Haitian living off less than two dollars per day, it is ranked 149th among 182 countries (United Nations Human Development Index). With the recent destruction caused by the earthquake of January 2010, Haiti is in a condition far more devastated than even these dire statistics suggest. In addition, the damage caused by Hurricane Thomas (Nov 5, 2010) left the whole country with flooded areas and forced many inhabitants from their homes. At the same time, an outbreak of cholera was confirmed on October 21, 2010 (Center for Disease Control and Prevention), which has caused over a thousand deaths. Since Haiti hasn't had a cholera case in more than 100 years, the population has no cholera immunity and the medical system has no experience treating it (CNN News, Nov 22, 2010).

Moreover, the Island of La Gonâve, often referred to as the "Forgotten Island of Haiti," is home to some of the poorest villages of the country due to its isolation from the mainland. Matènwa's water shortage situation has taken a backseat to relief efforts directed toward the nation's capital and the area around Port-au-Prince because La Gonâve was not directly hit by the earthquakes since the fault lines did not stretch underwater to the island.

Although the national government has its hands full currently with earthquake relief efforts, the local government of La Gonâve is still trying to address the dearth in drinking water.

In response to the water situation, the mayor of the port city Anse-à-Galets, formed the Water Platform, composed of charitable organizations working on the island. Current participants include the Mayors of Anse-à-Galets and Pointes-à-Racquette, the Deputy, Justice of the Peace Association, World Vision, Concern WorldWide, Sevis Kretyen, the Matènwa Community Learning Center, the Alleghany Wesleyan Church, the Methodist Church, Haiti Outreach and others. The members of the Water Platform have been working to address the water needs of the island by capping springs, building rainwater catchment cisterns and water systems and drilling wells. As of 2007, two non-profit groups have been actively drilling water wells on La Gonâve: Haiti Outreach, which has financed and drilled wells in 25 communities, and the Guts Church in Tulsa, Oklahoma, which has sponsored the drilling of 10 wells on the island. Zanmite is also working to address the developmental and economic problems facing the community of Matènwa, including water scarcity.

Zanmite is aware of the lack of water in the community and the effects it has on the life of the people of Matènwa, especially on the women. As one of the few organizations with direct contact with Matènwa, Zanmite has a primary interest in helping the villagers find a solution to water scarcity. Zanmite has suggested that our team might research better water collection methods. Seeing the depth of the problems faced by the villagers of Matènwa, and understanding the importance of finding a better method of water collection for them, our team, as engineering students, believes that our skills should be used to help bring them closer to a solution.

Background

Prior to its Independence, Haiti was once considered the "jewel of the French empire." It was France's richest colony, and the source of an estimated 20% of France's wealth. The nation of Haiti became an independent country in January 1, 1804, after the Haitian Revolution, originally led by Toussaint L'Overture, and then carried on by Jean-Jacques Dessalines. Haiti was the second country in the Americas to gain independence (after the US) and the only nation in history to have been liberated by slaves.

Unfortunately due to the racist attitudes of the US and France, both countries refused to recognize Haiti as an independent republic and went as far as imposing harsh economic embargoes. In 1825, France finally agreed to recognize Haiti's independence in exchange for reparations for lost revenue in slaves, a debt that stunted Haiti's economic development. For its part, the US refused to recognize Haiti until 1862, due to the fear that the notion of a free black republic would inspire rebellion by its own slaves in the South.

Unfortunately obtaining recognition as an independent republic was just one of many struggles. In the 19th century, France, Britain and Germany all took advantage of the small country economically the small country. And in 1915, the US under President Woodrow Wilson invaded Haiti with the excuse that Haiti's constitution denied foreigners (largely rich Americans) the right to buy up Haitian land. The US occupied Haiti for about twenty years, reinstituted slavery, emptied the national bank, and sold off land to US corporations. The US finally left in 1934.

Due to past corruption in the government and the lack of a stable democracy the country has been stuck in poverty ever since France imposed a heavy indemnity upon it after the Haitian Revolution. Economic exploitation by the United States and European powers during the nineteenth century prevented Haiti from achieving economic independence and prosperity. Another detrimental factor was the control that the United States had over Haiti's finances from the occupation in 1915 until 1947. In addition, the dictatorship of François Duvalier, later passed on to his son Jean-Claude, took advantage of government corruption and left the country vulnerable to crises.

Poverty is felt more deeply in the small villages of the island of La Gonâve, located west from Port-au-Prince, because this island has been deforested almost entirely by residents of the capital who saw it simply as a resource to be exploited, including destroying the forests to produce charcoal. In addition, the separation of this island from the mainland lessened the attention given to its citizens, who were living in the direst scarcity, by the central government and by international aid agencies.

Haiti's Political Crisis

Haiti is a country plagued by many unfortunate circumstances, many of the present issues being the result of its unstable government, and its inability to protect and serve its people. From its earliest days, the Haitian political system has been in a profound state of crisis. The media often portrays the issues of Haiti as self-inflicted and as a result of its own inability to govern itself. However, the roles played by outside countries, namely the US and France, are often overlooked, as when Haiti was denied recognition as an independent nation, and when it was invaded by the US.

A year before Haiti's most recent constitution, that of 1987, the dictator Jean-Claude "Baby Doc" Duvalier was overthrown. Combined with the reign of his father, François "Papa Doc" Duvalier, the Duvaliers ruled Haiti from 1957 to 1986. Since then, Haiti has experienced a series of weak, corrupt and disorganized authoritarian governments that have failed to provide for the basic social welfare and development needs of its people.

The period after the Duvalier reign became a power struggle for control over the Haitian government by competing political groups, including the new National Governing Council led by army leader General Henri Namphy, which ruled until early 1988. This new era was shaped by a series of provisional governments, and marked by revenge against members of the paramilitary force known as the *Tontons Macoutes.*

After the Duvalier reign, changes were made to the constitution concerning the position of the chief executive, making the president elected by popular vote for a period of five years. The president is not to be elected twice in a row, however he may serve a second term only after an interval of five years and must not run for a third term.

The country's first democratic elections finally took place on Dec. 16, 1990, following a campaign tarnished by political violence. Jean-Bertrand Aristide, a politically active Catholic priest well known for his support of the poor and opposition to Duvalier's system, won the presidential election. Aristide took office on Feb. 7, 1991, and formed a partnership with Prime Minister René Préval promising to improve the quality of government. Aristide wanted to carry out extensive reforms, which upset Haiti's business and military elite. He wanted the military to be under civilian control, and retired the Commander in Chief of the Army; he initiated investigations of human rights violations. He also banned the emigration of many well-known Haitians until their bank accounts had been examined.

The following September, Aristide was overthrown in a military coup led by Generals Raoul Cedras and Philippe Biamby, with the support of angered government officials and wealthy businessmen. Aristide was exiled for a three-year period, which he spent in Venezuela and later the United States. This coup was perceived by the United States as a threat to the international political security. For this reason, the United Nations approved Resolution 940, which authorized a United States-led multinational force to restore Aristide to office. Aristide returned to power in 1995, and upon his return, he disbanded the army and created a civilian police force. In the election of 1996, René Préval, Aristide's first prime minister and a prominent member of his Lavalas Family Party, was elected president.

In 2000, Aristide ran for a second term and won the presidential elections although the main opposition groups, formed the Democratic Convergence, protested over disputed parliamentary elections that his Lavalas Family Party had dominated six months earlier. Aristide's supporters were accused of using violence and intimidation to guarantee his victory at the polls. Electoral observers from the Organization of American States also expressed strong doubts about the validity of the elections. As a result, international governments, including the United States, suspended at least $500 million in aid. Despite concerns, on Feb. 7, 2001, Aristide was sworn in as Haiti’s president for the second time.

Political tensions in Haiti reached a peak in September 2003 when a former Aristide supporter, Amiot Metayer, leader of a militia in La Gonâve called the "Cannibal Army," was murdered. Before his death, Metayer was viewed as a hero in northern Haiti. Metayer's brother, Butteur Metayer, accused Aristide of having his private police kill Amiot Metayer. Aristide's government denied the allegations.

On February 5, 2004, the "Cannibal Army," took over Gonaïves, Haiti’s fourth-largest city, starting a minor revolt against Aristide. They burned the police station and looted it for weapons and vehicles, and continue their movement down the coast. By the end of February they had captured Haiti's second-largest city, Cap-Haïtien and controlled the capital, Port-au-Prince. Haitians fled their country on boats, seeking to get to the United States. After many attempts on his life and several death threats, Aristide was forced to "resign" under pressure from the United States. He was removed from office of president and was prevented from finishing his second term. He left Haiti on a U.S. plane escorted by U.S. security personnel.

The first presidential elections since the overthrow were held on February 8, 2006. Former president René Préval was re-elected with over 50 percent of the vote. Elections for legislative seats were held on April 21. In 2008, Parliament removed President Préval's prime minister from office as a result of severe rioting over food prices. The preferred replacement for the position was rejected by Parliament, marking the beginning of a prolonged period without a stable government.

As can be seen from this record of political struggles between rival governmental parties, Haiti has been subject to political violence and ensuing political corruption. It is no surprise that Transparency International ranked Haiti in 2009 as "one of the 13 most corrupts countries in the world, and the most corrupt country in the Western Hemisphere."

Haiti's Governmental Structure

In spite of having the constitutional framework for a working democracy, Haiti has experienced much corruption in its political structure and many instabilities arising from failures in the democratic process. Since its independence in 1804, Haiti has always been facing foreign interventions and dictatorial governments that prevented the growth of an uncorrupted democracy. Without a government representative of the people, basic human needs concerning employment, health, and adequate food and water have been ignored.

The legal system is based on the Roman civil law system. Haiti recognizes the jurisdiction of the International Court of Justice. There is a Supreme Court that is assisted by local and civil courts at a communal level. Through its Administration of Justice (AOJ) program, the United States has helped improve Haiti's judicial branch by training of hundreds of Haitian judges. The AOJ program ended in July of 2000; however Haiti's judicial system remains severely troubled—still lacking properly trained officials and resources to establish a secure and just society.

Haiti's government is today a semi-presidential republic where the President of Haiti is head of state directly elected by popular vote, the Prime Minister acts as head of the government and is appointed by the President from the majority party in the National Assembly, and the executive power is exercised by the President and Prime Minister, and both constitute the government.

The Parliament of Haiti is the legislature of the Republic of Haiti. The Parliament is bicameral, the upper house being the Senate and the lower house being the Chamber of Deputies. The Senate consists of thirty seats, with three of them being members from each of the ten administrative departments. The Chamber of Deputies has ninety-nine members (before 1987, eighty-three) who are elected by popular vote to four-year terms.

The government is organized unitarily, meaning that the central government delegates powers to the other departments without a need for consent. The current structure of Haiti's political system was set forth in the Constitution of March 29, 1987.

The Island of La Gonâve and the Village of Matènwa

La Gonâve is the largest of the Hispaniolan satellite islands and located to the west-northwest of Port-au-Prince in the Gulf of Gonâve. In the late fifteenth century, the island of La Gonâve was a vast paradise covered by great flora and fauna. When the Spanish slaved most of the native Hispaniolans, some of them sought refuge and fled to La Gonâve. Then, in the early 1600s, French buccaneers arrived on the island and stayed in caves until 1659, when France took control of the western part of La Hispaniola. After achieving independence from France, the former black slaves discovered the natural treasure of La Gonâve's soil and began cultivating bananas, yams, mangos, sweet potatoes, manioc, maize and other crops. Eventually, word spread out about the rich resources of the little island and more people settled there.

During the early 20th century, there were about 12,000 inhabitants on La Gonâve. When the United States invaded Haiti for the first time, from 1915 to 1934, a U.S. police station was established in the town of Anse-à-Galets. During this time the soil was still fertile, and natural resources were abundant, but as the population began to increase, the demand on these resources also increased. Soon, La Gonâve became a place to put unwanted members of society including the poor, vagabonds, convicts and political prisoners during the decades of oppressive rule by the Duvaliers. After 1988, the Haitian government exploited the remaining resources of the island to support the mainland. With the course of time and the constant demand for its resources, the quality of life on the island has deteriorated, since the deforestation of the island has led to low quality soil that can't retain runoff water.

Today, the island of La Gonâve has approximately 70,000 people. Matènwa is a small mountain village on La Gonâve Island, and like most of the mountain villages there, men, women and children work to grow what they can in small family garden plots. The crops they can cultivate are limited due to the rocky and dusty earth and uneven distribution of rain. The people in Matènwa often trade food and supplies with other villages in the island, but survive basically through a subsistence economy. Since the majority of the roads are dirt and any vehicular means of transportation is very expensive, traveling is extremely difficult for the villagers. On top of all of these issues, the shortage of water is the biggest concern for the people in the village of Matènwa.

Hurricanes

Matènwa is located on the northwest of Port-au-Prince in the Gulf of Gonâve. Because of the location of Haiti on the western third of Hispaniola, most parts of Haiti including Matènwa are in the rain shadow of the high mountains of the Dominican Republic, which captures the moisture from the Trade Winds that blow from Northeast to Northwest. In general, the higher the elevation, the cooler and wetter it gets. Due to the high altitude of Matènwa, indicated by the map in Appendix A, the weather there is relatively cooler and more humid than other parts of Haiti with approximately 1200 to 2,000 mm of rainfall every year, which is even more than the average rainfall in Florida (1,400 mm); however, in recent years there have been reports of increasing drought like conditions. The rain seasons are most likely in April, May, September and October, where the average rainfall could be up to 165 mm, as shown in Figure 3 (http://www.climatetemp.info/haiti/). Due to the special geographic location of La Gonâve in the middle of the hurricane belt, violent storms, gales and torrential rainfall usually hit the island of La Gonâve from September through November.

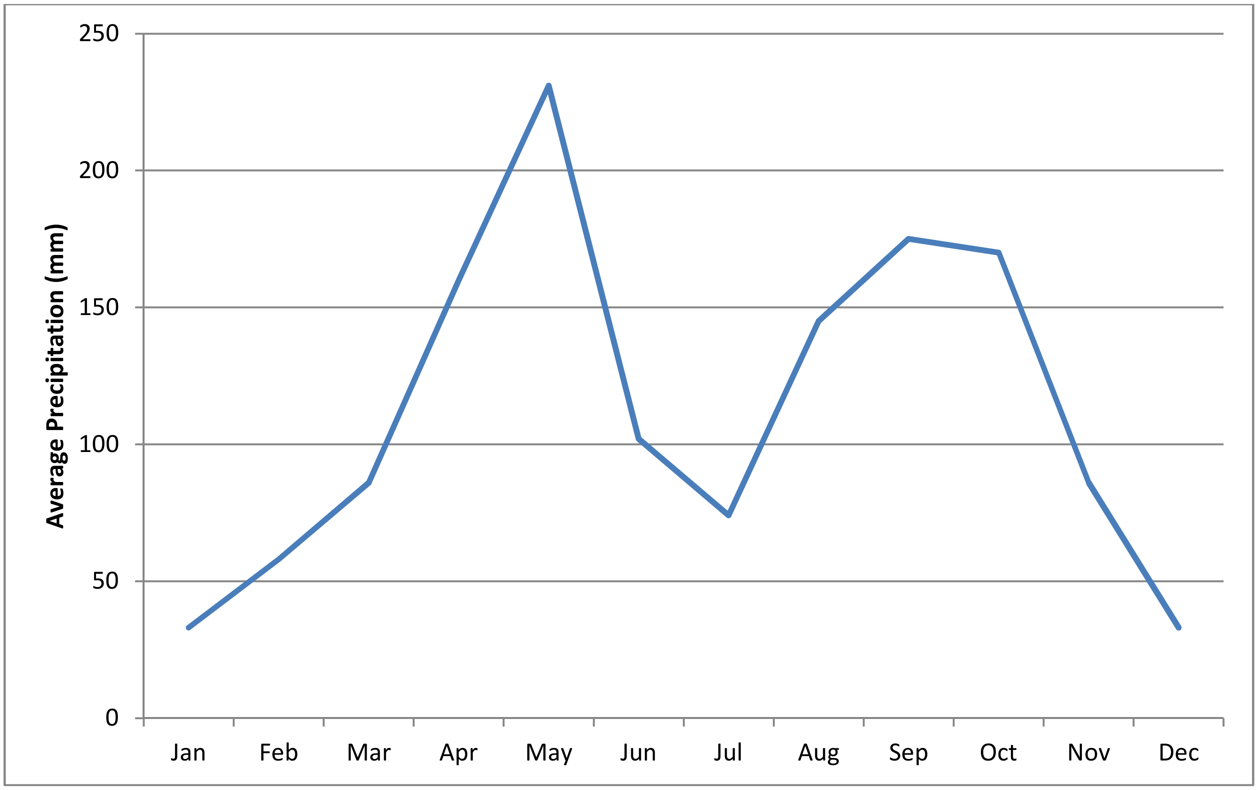

Figure 3 – Haiti's Annual Average Precipitation/Rainfall (http://www.climatetemp.info/haiti/)

Deforestation

"Almost all of the country's problems - natural disasters, food shortages, poverty - can be traced back to rampant deforestation." - Ethan Budiansky (Head of Trees for the Future)

Logging in Haiti to create charcoal has unfortunately been perceived as a temporary solution for the lack of fuel, but this short-term solution is creating another long term and permanent problem of devastating soil erosion, perpetuating the cycle of agrarian poverty among the people of La Gonâve. Already Haiti is experiencing severe and extreme deforestation as shown in Figure 4. The consequences of this deforestation are currently affecting the everyday lives of the Haitians and the consequences will soon become irreversible if immediate and swift action is not taken. These consequences have an instantaneous and a direct effect on the viability and success of building water catchment systems for the citizens of Matènwa.

Deforestation is the utter and complete destruction of the forest coverage for an allotted region. This devastation happens for a variety of economic and social reasons. When an area of land is deforested, there is a direct and parallel effect on the surrounding ecosystems. These effected ecosystems are left exposed to harsh elements that eventually lead to desertification, erosion of fertile topsoil causing the ground to become dry and the air to become arid as well as increased flooding and drought, siltation, an increased number of extensive landslides, decreased bio-diversity, radical temperature changes, pollution of water sources, and the increase of greenhouse gases. Deforestation is clearly detrimental to the environment and must be stopped. To combat deforestation, the general public must be re-educated to the dangers of eliminating forests and the proper ways to preserve and take advantage of the forest's resources, this is especially true in poverty stricken countries such as Haiti.

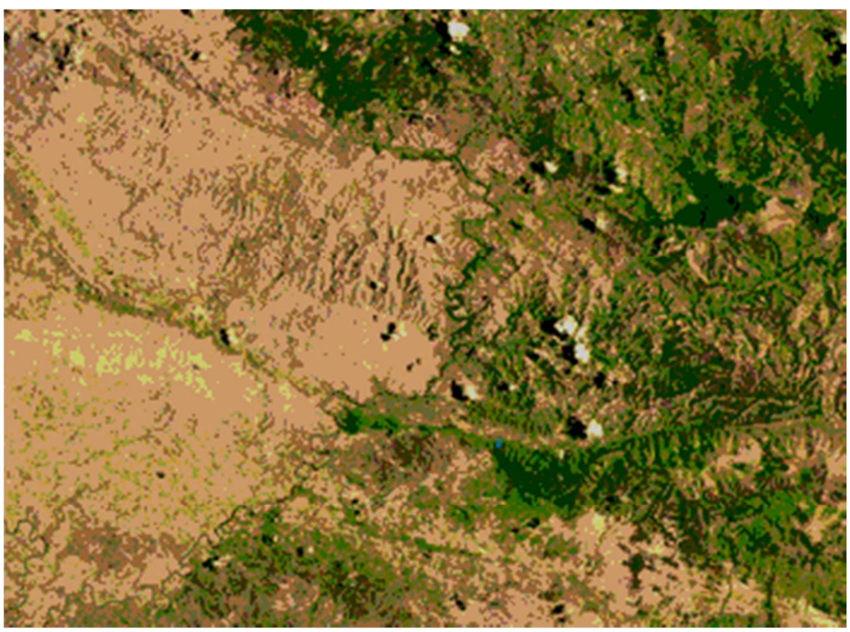

Figure 4–Vegetation Difference between Haiti (left) and the Dominican Republic (right) (Picture provided by NASA/ Goddard Space Flight Center Scientific Visualization Studio)

In 1954, after Hurricane Hazel, logging effects in Haiti quickly expanded out of control. The energy and food demands of Haiti were rising at a high rate, due to a rapid increase in population (a growth of 1.6% according to the World Development Indicators). Haiti also lacks natural petroleum resources, while also lacking the monetary ability to import such resources. This situation has forced the Haitians to rely on wood, in the form of charcoal, to be their main source of energy. Only ten percent of Haiti has electrical power, leading the country into an eighty percent dependency on charcoal as the major and leading source of energy. As Port-au-Prince stripped the mainland of Haiti of its natural forests, the people on the mainland turned to La Gonâve for its rich and lush forests as a solution to its charcoal shortage.

As Haiti faced an increased demand for energy, in the form of charcoal, it also faced an increased demand for food because of the explosive rise in population. According to the United Nations, Haiti has the highest fertility rate in the Western Hemisphere, while also having the fifty-first highest fertility rates internationally. Subsequently Haiti has watched its population grow from 3.1 million in 1950, to 9.8 million in 2008, to currently 10.2 million as described in Figure 5.

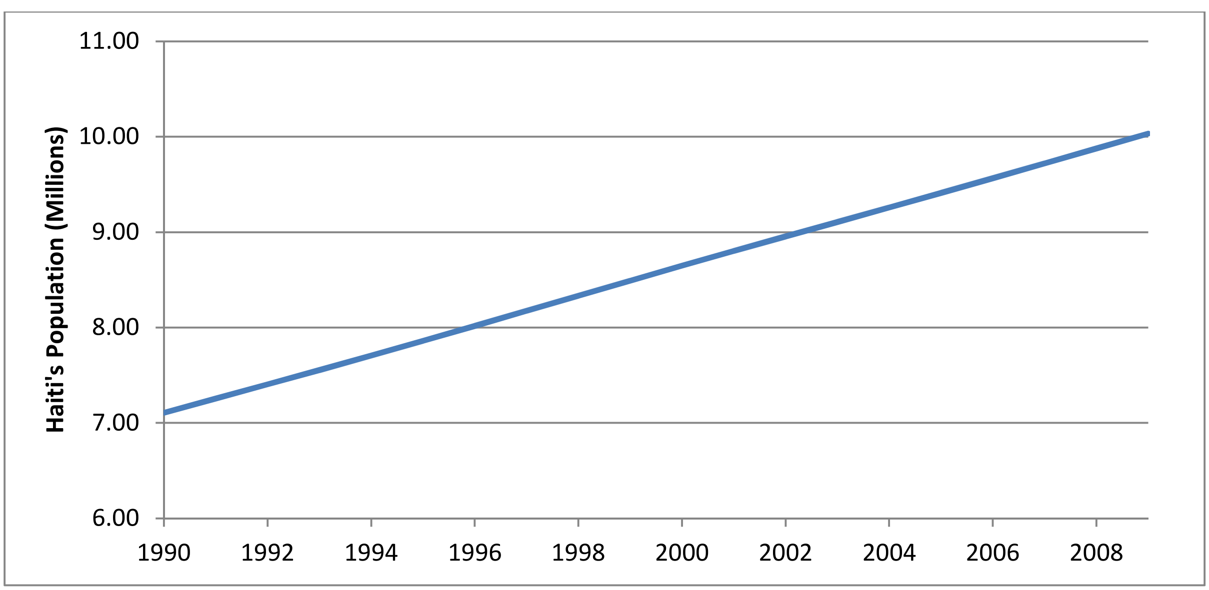

Figure 5 – Population in Haiti (in millions) from 1990 to 2009.
Provided by the World Development Indicators

The rapid increase in population has forced an increased demand for food, and this population explosion has also affected La Gonâve, where small scale subsistence farming can barely meet demand. Currently 66 percent of all Haitians work in agriculture. As farmers expanded their agricultural plots into the mountainous areas of Haiti, they cut down large amounts of trees. They turned the trees into charcoal and sold it to the mainland, as a second income source. Corn (or maize), which is a basic crop of Haiti, yields 800 kilograms per hectare. This production yield is low compared to corn production elsewhere in the world; it is half of what the rest of South America yields, and only a tenth of American farmers' yields per hectare. Due to the low level of education and training of farmers in Haiti, their farming techniques use up all the nutrients in the soil, making crop yields low and forcing them to seek more fertile soil. The empty land they leave behind is starved of nutrients and does not have the resources to allow trees to grow in its wake. Today it is estimated that thirty percent of Haiti is unsuitable for cultivation.

The rapid increase in population has also forced an increased demand for charcoal as a source of energy. With the mainland stripped of its forests, it turned to La Gonâve as a source of charcoal. Due to the poor education of the charcoal farmers, the logging of forests was done in a way that was detrimental to the replanting and revitalization of forests. Figure 7 shows piles of woods being stacked to be burned into charcoal. Poverty in La Gonâve creates a situation where a charcoal farmer must try to obtain as much wood as possible to make charcoal. This leads to the uprooting of stumps and roots, to be used as a charcoal source as well, which causes vast ecological damages. By digging up roots, the charcoal burners are immediately damaging the water source and the water retention mechanism in the soil, by drying it up and making it uncultivable. This uprooting also ends the nitrogen cycle between the roots and the soil, which limits the remaining nutrients, while removing a carbon rich biomass, which would have fertilized the soil. The roots are also important in protecting seedlings, while the forest tries to regenerate. This devastating system of logging, has led to the deforestation and desertification of much of Haiti, as the map in Figure 6 displays.

Figure 6 – Map of La Hispaniola

Figure 7– Charcoal farmers stacking wood to be burned into charcoal (Picture provided by Jonathan Auch)

Due to the expansion of farms and the growing demand for charcoal, Haiti has lost many of its forests. In 1923, it was estimated that sixty percent of Haiti was covered in forests. By 2006, 98% of the forests were cut down leaving only 1.4% of Haiti with forests. Haiti no longer has old growth forests. Currently Haiti burns 30 million trees, 4 million cubic meters, or 720,000 metric tons worth of trees annually. The deforestation in La Gonâve has led to environmental repercussions, which have both direct and indirect effects on building a water catchment system in Matènwa.

Effects of Deforestation on a Rooftop Water Catchment System

The effects of deforestation are extensive. They affect every part of the ecosystem including manmade infrastructure, including a rooftop water catchment system. To ensure success of this proposed project, the present state of the ecosystem must be taken into consideration. To do so we will explore three of the major effects of deforestation on the surrounding ecosystem, and how these effects have implications for the construction of a water catchment system:

- Pollution of drinking water, due to siltation
- Disruption of the water cycle, making rain seasons less cyclic and more sporadic.
- Increasing the severity and number of droughts.

These consequences of deforestation have the highest potential of affecting or altering the success of any water catchment system.

Siltation

Desertification is a byproduct of deforestation, which is the degradation of land due to aridity. The topsoil, which was once moist is dried out, and is now vulnerable to be blown or washed away. This dried topsoil is rich in nutrients and when it enters a body of water it stays suspended, also known as a suspended load. It is important to note that silt particles are smaller than sand particles but larger than clay particles. When suspended silt remains in a body of water it becomes a pollutant, this is known as siltation. In Haiti 33% of the country is severely eroded, 15,000 acres of topsoil are being washed and blown away annually. The environment around Matènwa is particularly affected by deforestation, and is prone to soil erosion. If this silt entered a water catchment system it could have the following devastating effects:

- Added stress on the ceramic filtration system
  - If silt is blown into the water catchment system, it would create added stress on the ceramic water filter. This would place more wear and tear on the system, creating a higher probability of damages.
  - As more silt enters the system, it will eventually become oversaturated and the silt will settle to the base of the water tank, clogging the pipes and not allowing water to pass through them. This would render the system unusable.
- Reduced water storage capacity
  - As silt builds up in the water tank, it supplants the water that the tank is supposed to hold. This creates a situation where not enough water can be collected and stored

for the dry season.

- Stimulation of algae and other pollutant growth
  - Silt is very high in nitrogen and other minerals. This is attractive to algae and stimulates high growth rates. Not only does this make the water even more unsanitary to drink, it also causes stress on the ceramic filtration system, and reduces the water storage capacity.

Siltation is a side effect of deforestation that must be taken seriously to ensure the long term success of the rooftop catchment system. Three approaches must be considered to ensure the proper protection of this system. First, local people must learn about the dangers of siltation. Second, a mechanism must be put in place to allow the settled silt on the bottom of the tank to be removed. Third the entrance point of the tank should be protected with a silt screen, which will allow water to pass through it while not allowing silt to do so. Although siltation has the potential to negatively impact the rooftop water catchment systems, there are ways to prevent it from doing so.

Sporadic Rain Seasons

Although the rainy season in Haiti has generally remained consistent, it has been observed that the rains are no longer as regular or as heavy as they used to be. This can be directly attributed to deforestation and its destruction of the natural ecosystem water cycle. To understand how deforestation affects the water cycle, we must review how a forest contributes to the local rainfall as seen in Figure 8. The canopy of trees trap moisture in the forest air that is later evaporated into the atmosphere, which slightly increases moisture and rainfall. The main source of moisture that is evaporated into the ecosystem water cycle is due to evapotranspiration. *Stomatal transpiration* is the diffusion of water into the atmosphere. The water in the environment is then evaporated and stored in rain clouds. This humidity is later discharged on a different area of the forest. This cycle allows the same water to be recycled upon different sections of the forest several times.

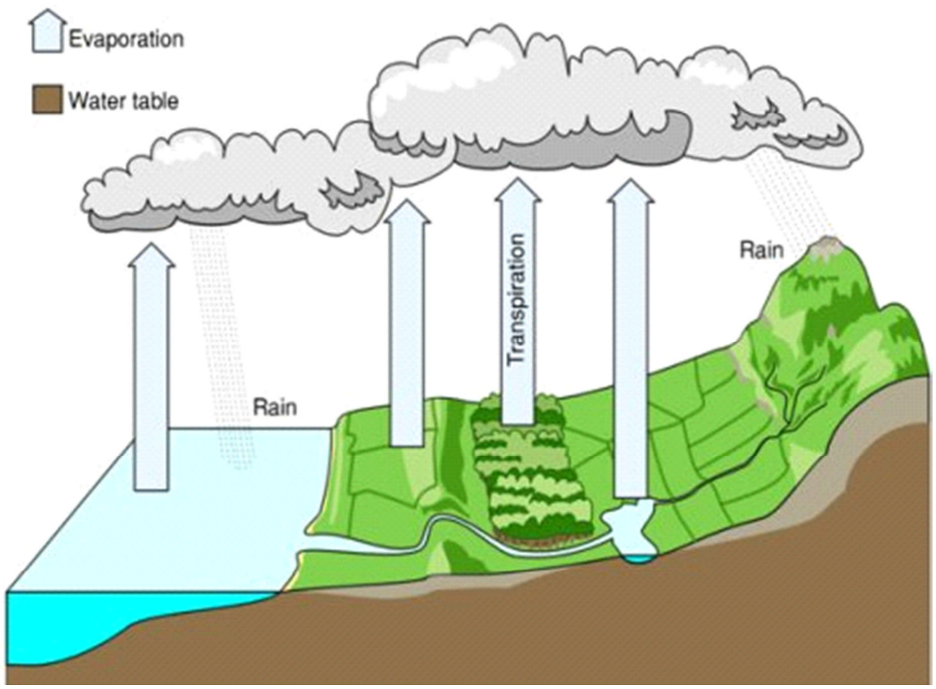

Figure 8– Basic cycle of transpiration and evapotranspiration (http://www.superwatergel.com/watercycle.html)

Currently only 1.4% of Haiti is covered with forest and this has created a severe reduction of evapotranspiration, essentially eliminating an effective and active rain cycle. This ecological damage has led to the rain seasons being less regular than they had been. The irregularities have not become severe yet, but the possibility that the rainy season will become irregular could have a significant impact on a rooftop water catchment system. La Gonâve is surrounded by water, which is evaporated into the atmosphere, and helps keep its rain season consistent. At the moment we do not see a direct effect from the lack of evapotranspiration, but it is important to advise the citizens of Matènwa to keep track of previous rain seasons, and to teach them how to prepare in case of an emerging pattern of rain irregularity. It will be important for Matènwa to carefully and accurately record, on a daily basis, when and how much rain falls. Data collected over a decade could be analyzed to determine if there are approaching irregularities in the cycle of the rain seasons. The citizens of Matènwa would then have more time to prepare for these increasing irregularities.

The Severity and Number of Droughts

The roots of trees help control the flow of water. The roots absorb water, which during heavy rain seasons help prevent flash flooding. During dry and arid seasons, the roots help maintain moisture in the soil, which allows the limited rain water and runoff from mountains to continue to flow in rivers at an even rate. The area around Matènwa has been deforested, which makes it prone to flash floods, and equally important, to severe droughts. Although the water catchment system proposed by this project depends on regular rainfall, we still must note the possibility of severe droughts affecting Haiti unless the cycle of deforestation can be arrested. As the severity of drought increases, the demand and stress on the drinking water supply and the brown water supply intensifies. As droughts become more severe, the amount of drinking water needed to sustain the homeostasis of the human body increases. Surrounding trees, livestock, and farms also need an increased amount of water to sustain them through dry periods. This increased stress on the water supply can cause the community to run out of necessary water before the next rain season arrives. Although there is limited direct effects of severe drought in Haiti, Matènwa must be prepared for such possibility if deforestation is not stopped. The solution to prevent or limit the negative effects of drought ultimately rests with preparing the local people to deal with the consequences of drought and teaching them about deforestation and the water cycle.

The deforestation of Haiti has been devastating and its effects have caused consequences that could very soon be irreversible. The deforestation of Haiti has been caused by not only the rise in demand for energy and food, but also the lack of foresight of charcoal farmers. It is only by re-educating these farmers on proper ways to harvest the forest for its charcoal, partnered with the replanting of forests, can Haiti be saved from total ecological disaster. Haiti needs to look to countries that successfully overcame deforestation and desertification. South Korea continues to be a model for reforestation and strives to assist other countries with their reforestation needs and planning.

South Korea's forests were devastated by the Japanese during WWII and further by the Korean War. Today 64% of South Korea is once again covered by forests. The Korean Forest Services devised a sustainable forest management system, which it shares with other countries. The system is composed of several stages of planting and growth, coupled with the education of its citizens and forestry workers. The Korean plan addressed the daunting risks of shortage of fuel (Korea at that point used wood as fuel, like Haiti currently does), floods, droughts, soil erosion, and natural disasters. Today 1.06 million hectares have been reforested in South Korea. Korea is a model to the rest of the world, and has continued to assist several other countries with their reforestation programs including but not limited to China, Indonesia, Mongolia, and Myanmar. This type of long term solution would address the problems associated with deforestation that Haiti currently faces.

We have laid out the effects of deforestation and the potential ramification it may have on a rooftop water system dependent upon rain. The system must be built properly to minimize the effects of siltation arising from current deforestation. In the long term, through proper education, as well as data collection and analysis of irregular rain patterns, measures can be taken to reverse the negative effects of deforestation. Deforestation and desertification in Haiti has several negative consequences and is severely hurting the country and its citizens; a self-sustainable rainwater collection system in Matènwa will be jeopardized by these negative consequences until more is done to reverse this destructive process.

Water Usage in Haiti

In Haiti, the per capita internal renewable water resources consisted of 1,549 cubic meters per person in 2001, the per capita natural renewable water resources consisted of 1,670 cubic meters per person in 2002 (EarthTrends 2003), and the per capita water withdrawals of the actual renewable resources consisted of 116 cubic meters per person, of which 94% was used for agricultural purposes, while 5% was used for domestic purposes and 1% for industrial purposes, as shown in Figure 9 according to the Food and Agricultural Organization of the United Nations (FAO 2005).

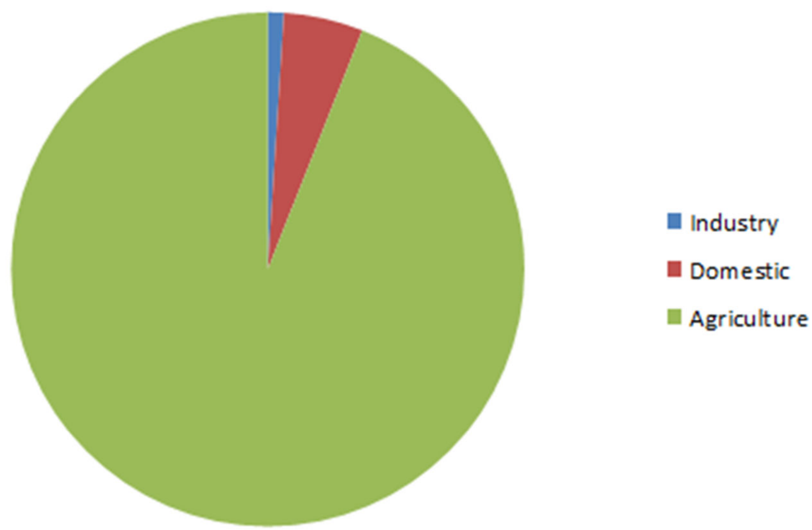

Figure 9 - Surface Water Withdrawals by Sector in Haiti (FAO, 2005)

The average per capita water usage per day is approximately 3.96 gallons (15 liters) per person per day for their domestic needs, as shown in Figure 10 (Data360.org, 2006), but in developing nations there is also a great need for water in agricultural activities. In Matènwa, the water that runs-off goes into the soil but doesn't stay there; it gets filtered down to underground streams due to the soil porosity. However, this water could be used for agricultural purposes if it were caught by a ground catchment system and used as "brown water" (see below).

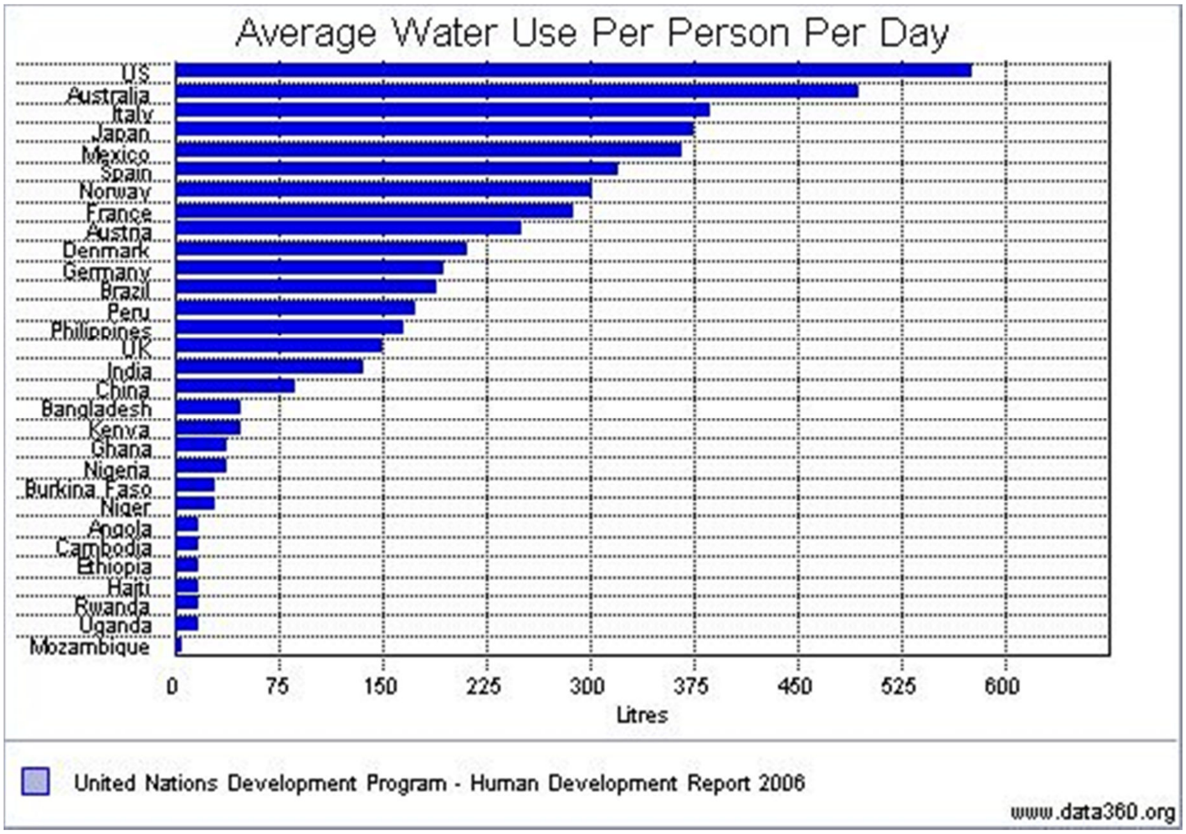

Figure 10– Average Water Use per Person per Day in Litres

Drinking Water

Obtaining clean drinking water has been a difficult task for the country of Haiti as a whole, even prior to the Earthquake of 2010 and the ensuing cholera epidemic. The majority of its ten million inhabitants rely on springs and rivers and a few wells to meet their water needs. Unfortunately a great deal of this water is loaded with bacteria and parasites, chemicals and other pollutants. The foul water has undermined many aspects of life in Haiti. It has caused chronic diarrhea, hepatitis and most recently, cholera. The diseases have filled hospital beds, kept children out of school and grown-ups from work, and water-borne diseases have caused many deaths.

In Haiti, the main public institutions responsible for supplying water are owned by the government, each created by its own law: CAMEP (Centrale Autonome Métropolitaine d'Eau Potable), responsible for the Port-au-Prince metropolitan area, and DINEPA (National Directorate for Water Supply and Sanitation, formally the SNEP Service National d'Eau Potable), responsible for secondary cities and, in theory, for rural areas.

Since sanitation is not included among the obligations of CAMEP and DINEPA, Haiti has no institutional responsibility for sanitation either. Both entities theoretically are under the authority of Water Boards, including representatives of several ministries. Since these boards have not met for a long period, the Minister of Public Works, Transport and Communications (MTPTC) controls both units. However, the Ministry of Public Works currently does not have a water and sanitation board and plans on creating one. The potential board would be in charge of developing policies and supervising the public operations in the region, and other responsibilities (according to DINEPA).

The water reform unit (URSEP) in MTPTC, the project management unit of an Inter-American Development Bank (IDB), funded water reform project. One of URSEP's functions is the execution of water and sanitation interventions in the smaller cities with systems run by SNEP. It also encourages self-sufficiency for the local divisions of DINEPA.

There are many committees called CAEPs (Comités d'Aprovisionnement en Eau Potable) responsible for water systems in small towns. How formal and effective they are, varies significantly. The best water committees perform several tasks to ensure quality and to be approved by DINEPA. However, in cash-strapped Haiti, many water committees fall short of these expectations. There are no collaborations of water committees at the municipal, departmental or national level.

Unfortunately the Haitian government does not have set regulations to ensure the safety of drinking water. As mentioned before, there are many agencies under CAMEP and DINEPA that do supply water, however it is generally untreated. With Haiti's water been rated as the worst in the world, waterborne diseases are nothing new to camp residents -- they regularly report suffering from skin rashes and diarrhea from the consumption of contaminated water. The detailed waterborne pathogens are described in Table 1. Due to the lack of alternative water sources rather than the lack of education, people end up drinking dirty water; 39 percent of respondents in a study conducted by the Institute for Justice & Democracy in Haiti (IJDH) in July reported that they drank from tanks and cisterns even though they feared it was contaminated because they have no other options.

Table 1 – Waterborne pathogens (World Health Organization)

Pathogen	Health significance[b]	Persistence in water supplies[c]	Resistance to chlorine[d]	Relative infectivity[e]	Important animal source
Bacteria					
Burkholderia pseudomallei	High	May multiply	Low	Low	No
Campylobacter jejuni, C. coli	High	Moderate	Low	Moderate	Yes
Escherichia coli – Pathogenic[f]	High	Moderate	Low	Low	Yes
E. coli – Enterohaemorrhagic	High	Moderate	Low	High	Yes
Legionella spp.	High	May multiply	Low	Moderate	No
Non-tuberculous mycobacteria	Low	May multiply	High	Low	No
Pseudomonas aeruginosa[g]	Moderate	May multiply	Moderate	Low	No
Salmonella typhi	High	Moderate	Low	Low	No
Other salmonellae	High	May multiply	Low	Low	Yes
Shigella spp.	High	Short	Low	High	No
Vibrio cholerae	High	Short to long[h]	Low	Low	No
Yersinia enterocolitica	Moderate	Long	Low	Low	Yes
Viruses					
Adenoviruses	Moderate	Long	Moderate	High	No
Enteroviruses	High	Long	Moderate	High	No
Astroviruses	Moderate	Long	Moderate	High	No
Hepatitis A virus	High	Long	Moderate	High	No
Hepatitis E virus	High	Long	Moderate	High	Potentially
Noroviruses	High	Long	Moderate	High	Potentially
Sapoviruses	High	Long	Moderate	High	Potentially
Rotavirus	High	Long	Moderate	High	No
Protozoa					
Acanthamoeba spp.	High	May multiply	Low	High	No
Cryptosporidium parvum	High	Long	High	High	Yes
Cyclospora cayetanensis	High	Long	High	High	No
Entamoeba histolytica	High	Moderate	High	High	No
Giardia intestinalis	High	Moderate	High	High	Yes
Naegleria fowleri	High	May multiply[i]	Low	Moderate	No
Toxoplasma gondii	High	Long	High	High	Yes
Helminths					
Dracunculus medinensis	High	Moderate	Moderate	High	No
Schistosoma spp.	High	Short	Moderate	High	Yes

Note: Waterborne transmission of the pathogens listed has been confirmed by epidemiological studies and case histories. Part of the demonstration of pathogenicity involves reproducing the disease in suitable hosts. Experimental studies in which volunteers are exposed to known numbers of pathogens provide relative information. As most studies are done with healthy adult volunteers, such data are applicable to only a part of the exposed population, and extrapolation to more sensitive groups is an issue that remains to be studied in more detail.

[a] This table contains pathogens for which there is some evidence of health significance related to their occurrence in drinking-water supplies. More information on these and other pathogens is presented in chapter 11.

[b] Health significance relates to the severity of impact, including association with outbreaks.

[c] Detection period for infective stage in water at 20° C: short, up to 1 week; moderate, 1 week to 1 month; long, over 1 month.

[d] When the infective stage is freely suspended in water treated at conventional doses and contact times and pH between 7 and 8. Low means 99% inactivation at 20° C generally in <1 min, moderate 1–30 min and high >30 min. It should be noted that organisms that survive and grow in biofilms, such as *Legionella* and mycobacteria, will be protected from chlorination.

[e] From experiments with human volunteers, from epidemiological evidence and from animal studies. High means infective doses can be $1–10^2$ organisms or particles, moderate $10^2–10^4$ and low $>10^4$.

[f] Includes enteropathogenic, enterotoxigenic and enteroinvasive.

[g] Main route of infection is by skin contact, but can infect immunosuppressed or cancer patients orally.

[h] *Vibrio cholerae* may persist for long periods in association with copepods and other aquatic organisms.

[i] In warm water

Brown Water

The water that gets recycled from non-consumption purposes, such as dishwashing, and then is used for purposes like irrigating plants, is referred to as "brown water". Untreated rainwater is normally treated as brown water and is suitable for non-potable uses such as lawn and garden watering or irrigation, clothes washing, toilet flushing, firefighting, among other uses. Although rainwater has the purest quality, it gets polluted by the acidity of the air as it falls and by the surface where it lands. After falling down and reaching the rainwater harvesting system, rain can be fed to livestock and pets. However, it is highly recommended that it is filtered and/or boiled before being used for potable purposes, in order to eliminate possible contaminants, bacteria, and other materials that might be present.

Community Empowerment

"Empowerment conveys both a psychological sense of personal control or influence and a concern with actual social influence, political power, and legal rights. It is a multilevel construct applicable to individual citizens as well as to organizations and neighborhoods; it suggests the study of people in context."[1] In our efforts to develop new technology to collect water for the community of Matènwa, community involvement must play a key role in successfully resolving the problem of water shortage and implementing any new technological means. One method useful for promoting involvement in such projects is called "participatory rural appraisal" (PRA). PRA is an approach that many agencies, including non-governmental organizations, use to empower local people from specific regions to take vital roles in local

[1] http://www.springerlink.com/content/u8153873232wq60u/fulltext.pdf

projects. Such roles may include information analysis and the practice of critical self-awareness, as well as taking responsibility and sharing individual life knowledge and conditions to plan and act.

Understanding Participatory Rural Appraisal

A study elaborated by Robert Chambers from the Institute of Development Studies defined PRA as an "an approach and method for learning about rural life and conditions from, with and by rural people" (Chambers, 1994). This approach came to life in the early 1990s and encompasses the different ways by which the local population of Matènwa might be able to analyze and understand the problems they are facing and take necessary action themselves to address such problems. PRA greatly encourages the idea of community involvement as a step towards self-sustainability. The latter has been successfully adopted in many countries such as Bangladesh, Botswana, Ethiopia, India, Kenya and Sudan among others. The use of PRA in those countries was aimed at the management of natural resources through conservation of soil and water, development of forestry, fisheries and wildlife preservation, the betterment of living conditions for the poor, agricultural and health services as well as in the introduction of programs for women. These varied successes suggest that PRA is an appropriate approach in our case since it has been efficient in countries having an unstable economic situation (Chambers, 1994).

The following are different methods of analysis that are at the root and provide the very basis and influence for PRA.

- Activist participatory research

- Agro-ecosystem analysis
- Applied anthropology
- Field research on farming systems
- Rapid rural appraisal (Chambers, 1994)

Activist Participatory Research

This type of research includes methods that entail direct communication and "participatory research" for the people involved to raise awareness and "empower their action" (Chambers, 1994). It reinforces the idea that the people in need of help are able to analyze their condition and participate in finding a solution to the problem. It encourages "underprivileged communities" to be self-assertive and self-sustainable. In our case, it can be used to enable the people of Matènwa to become actively involved in finding an efficient solution to the problem of water shortage. Participatory research originated in the early 1970s and has had a widespread use around the globe. For instance, in 1983, Activist Participatory Research was implemented in Bangladesh and afforded poor people a chance to help local authorities in the development of a "power structure" for 10 villages (Chambers, 1994). Activist Participatory Research offered input to Participatory Rural Appraisal in terms of conceptual rather than methodological perspectives. The report by Robert Chambers speaks of three main ideas that both approaches have in common:

a) that poor people are creative and capable, and can and should do much of their own investigation, analysis and planning
b) that outsiders have roles as conveners, catalysts and facilitators

c) that the weak and marginalized can and should be empowered (Chambers, 1994)

Agro-ecosystem Analysis

Agro-ecosystem Analysis originated in 1978 in Thailand and was used extensively in Southeast Asia before its worldwide use. This method provides a more systematic and mathematical perspective to anthropological research. It involves the use of sketches, diagrams and finding relationships in terms of time (calendars and long term trends) and space, including the use of maps among others conceptual tools. It was later modified when utilized in Pakistan for a support program in northern villages (Chambers, 1994). Agro-ecosystem analysis evolved further to contribute properties to other methods, including Rapid Rural Appraisal (RRA) and Participatory Rural Appraisal (PRA). These methods use both a systematic observational approach as well as a schematic approach when analyzing an issue before taking action.

Applied Anthropology

"Social anthropology in its classical forms has been concerned more with understanding than with changing, but especially in the 1980s applied anthropology, and development anthropology, became more recognized as legitimate and useful activities"(Chambers, 1994). Applied anthropology deals more with knowledge of a people rather than their plan of action. Social anthropology played a key role in promoting the ideas and showing how invaluable rural people's knowledge and opinions could be. One successful implementation of this approach was in relation to health and nutrition assessment, which involved brainstorming and gathering ideas through focus groups, interviews and conversations (Scrimshaw and Hurtado, 1987; Scrimshaw and Gleason, 1992). According to Robert Chambers (1994), the extensive use of social anthropology stemmed out to provide valuable characteristics to PRA in terms of behavioral and social analysis such as:

a) the idea of field learning as flexible art rather than rigid science
b) the value of field residence, unhurried participant- observation, and conversations
c) the importance of attitudes, behavior and rapport
d) the validity of indigenous technical knowledge (Chambers, 1994)

Field research on farming systems

Field research did not make direct and immediate contributions to PRA unlike applied anthropology. It was effective in the early 1960s in giving a sense of direction to the "farming practices "adopted at that time. While the study of farming practices was being conducted, focus was simultaneously given to the study of the capabilities of farmers. A study in 1991, conducted by Clive Lightfoot and his colleagues from different governmental organizations "showed through widely influential videos how capable farmers, women and men, could be in conducting their own trials, assessments and analysis" (Chambers, 1994). Field research on farming systems helped in improving the mindset that people from poor areas, though deprived of formal education, could provide valuable additional insight to work towards improving their condition.

Rapid Rural Appraisal

According to Robert Chambers (1994), Rapid Rural Appraisal (RRA) came to life in the 1970s due to several reasons: "dissatisfaction with the biases" of investigators, time spent in processing questionnaires surveys and results, and a concern for a more "cost effective method of learning." RRA encouraged the idea of lessening biases against the poor and helpless who are not given the opportunity to offer their insight on issues regarding the development of their region. In addition, RRA proved to be a quicker and more productive way to gather data on a large scale compared to carrying out questionnaire surveys, which prove to be tedious in the making and processing of information. Also, this method proved to be cost-beneficial due to the progressively known fact that "rural people were themselves knowledgeable on many subjects that touched their lives."

Principles of Participatory Rural Appraisal

Participatory Rural Appraisal (PRA) is still developing. Although it is a young concept, it is still important to remember that PRA came about through a series of "trial and error" and is still developing. The following principles are used to help define what PRA is today:

a) Reversal of learning
b) Learning rapidly and progressively
c) Offsetting biases
d) Optimizing tradeoff
e) Triangulating
f) Seeing diversity
g) They do it
h) Self-critical awareness
i) Personal responsibilities
j) Sharing of information and ideas

Many of the principles have overlapping concepts and effects. To understand PRA more completely, the principles can be divided into two different categories. The first category includes the principles that are relevant to learning, understanding, and empowerment. The second category contains the principles that validate information and assist in the utilization of information.

PRA stresses the idea of community empowerment, allowing for the community to take ownership for all steps and processes of projects. To do so, PRA lays out a loose guideline of concepts, such as “reversal of learning,” “they do it,” “self-critical awareness,” “personal responsibility,” and “sharing of information and ideas.” PRA contradicts the previously held idea that indigenous people lack the ability and the knowledge to be involved in the process of mapping, analyzing, planning, and implementing. Instead PRA embraces the idea of indigenous technical knowledge (ITK), meaning “Rural people were themselves knowledgeable on many subjects that touched their lives.” To empower the locals to engage in the process, outsiders need to create confidence, interest, and opportunity for the people they have come to help. The first step in this process is “reversal of learning.” Reversal of learning is a matter of *emic* learning replacing *etic* observations, thereby creating opportunities for the outsider to engage in the daily lives and activities of the locals, which also assist in building quickly a good rapport (*emic* refers to perceptions that are regarded as meaningful by the local people, while *etic* indicates those observations that have meaning for the outsiders). “The practitioner must remain honest, while showing humility, respect, patience and interest in what the people have to say and show.” To empower the community, it is important that the local people take ownership over of the process as much as possible. The easiest way to do this is to let locals have ownership of the process by allowing them to engage in the collecting and analyzing of information, in planning how the information will be used, and in implementing actions that they agree upon. This attitude and philosophy toward the process of rural development is often referred to as “handing over the stick.” The outsider is catalysis to conversation, but sits back and allows the locals to analyze and plan. The outsider’s role is to observe and listen to the process. Often, during the process, local people are able to utilize their personal knowledge of the natural resources, and may have already tried certain processes to achieve greater efficiency and effectiveness. When local people analyze their own data, plan their own action strategy, and implement it, locals then take ownership of the process. In short, “they do it,” rather than having some well-meaning outside agency “do it for them.” During this process it is important for the outside to be “self-critically aware,” and to practice “personal responsibility,” to ensure quality and creativity in the solutions that are being considered. Outsiders must allow the practitioners to learn in the field and to encourage them to learn from their mistakes by creating “informed improvisions.” The outsider must be aware of their own behavior and the effects it has on the community and the process. When an outside benefactor observes and then corrects behavior that discourages indigenous self-teaching and experimentation, local people have an opportunity to learn for themselves how to address their own problems. Of course, the observer must use their best judgment at all times; there is no true blueprint, manual, or rules on how to enact PRA. All together these principles lead to community empowerment and engage local people in all processes of change.

Although outside assistants and benefactors allow locals to take control and ownership over the projects, they must still validate information and seek out a diverse range of opinions about the problem. While we have the potential to collect some information about water harvesting that is not available in Matènwa, a study made in Nepal shows that it is better to collect data directly from local people. In May of 1990, farmers in Nepal used seeds to display the days of rainfall, and sticks to measure the volume. The data they presented contradicted the data from the local rainfall system. It was later discovered that the farmers' measurements were closely linked to the "agricultural utility and weighted by recent experiences." The farmers' data in turn ended up being more relevant and superior to the averaged meteorological data. Nevertheless, the data that is offered by the locals must be "triangulated" while "seeking diversity." Triangulation means "cross checking, progressive learning and approximation through plural investigation." As information is gathered in Matènwa about possible ways to implement rooftop catchment of rainwater, a number of factors must be taken into consideration:

a) Methods
b) Types of item or sets of conditions
c) Points in range or distribution
d) Individuals or groups of analysts
e) Places
f) Times
g) Disciplines
h) Investigators or inquirers

These types of criteria insure that information about water shortage and methods of water collection are rich and complex, and pieces of data can be cross checked and validated. Triangulation often uses at least three sources of information to cross check data. It also allows observers to see any outliers to the norm, which gives an opportunity to “seek diversity.” It is often thought that dissenters in data are negative and detrimental to the worthiness of the data, but in PRA disagreement is seen as “maximizing the diversity and richness of information.” Whoever implements improvements in local water collection methods must notice and investigate anomalies, so that they can “offset biases.” It is important to listen and seek out poorer less influential members of the community as well as women so that their concerns and priorities are heard and understood, thus providing a well-rounded pool of data.

Tools of Participatory Rural Appraisal

Participatory Rural Appraisal allows for several tools to be utilized simultaneously, while allowing for flexibility so not all tools must be used and new tools can be immediately innovated for use in the field. PRA promotes the use of visual representations, and encourages local people to analyze the data representations they have created. PRA emphasizes innovation and flexibility in its methodological tools. The tools of RRA and PRA overlaps, but we will focus primarily on the tools that are most relevant to PRA, which are broken up into three categories although all three rely heavily on each other.

a) Visualized analyses
b) Interviewing and sampling methods
c) Group and team dynamics methods

Visualized analyses: include but are not limited to activities that require the locals to create charts, maps, diagrams and rankings. These are commonly found to be useful in engaging local people in appraisal, planning, monitoring, evaluation, and investigations. It is also a valuable tool in organizing data into useful and relevant categories and mapping data into regions, which can be openly discussed, criticized and altered by all members of the community. It is important to "interview" the visual representations, as a way to encourage the analysis of the data created.

Interviewing and sampling methods: can be useful in many parts of the PRA process. It allows the outside observer to create categorizes for "visualized analyses," and later on encourage the analysis of the data. It also reveals the priorities and concerns of all members of the community and helps triangulate the data created.

Group and team dynamics methods: engage the community to discuss and debate collected data, thus assisting in the establishment of accurate data. Often when there is a contradiction in information, especially in visual data, the community can clarify or alter the data through group discussions, a critical part in the triangulation of data. This process is also a key cog in the creation of new innovations, which produce more efficient ways out of "group discussions and brainstorming."

These three categories of tools, when utilized together, create the basis of PRA. It empowers the community to be engaged and creates ownership of the project. It allows for the flexibility of systems, and encourages innovation. It allows the community to be the main participant in the project, and often drives the project to success.

The paucity of sanitary drinking water is a serious problem that affects the entire community of Matènwa. The soil in Matènwa lacks the ability to retain water creating severe water shortages, and as a result, the women of Matènwa have to walk two hours a day to get a limited 5 gallons of water, which is riddled with diseases such as cholera and hepatitis. The death of half of all Haitians is attributed to such unsanitary water, and has pushed the infant mortality rate to 63.7/1,000, the highest rate in the Western hemisphere. This grave heath concern clearly violates the United Nations' Universal Declaration of Human Rights Article 25 Section 1, which states:

> *Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing and medical care….*

In addition, several catastrophes, including the recent earthquake (January 12, 2010) that left 319 thousand people dead, the recent cholera outbreak that killed 3,600 people, and the recent hurricane, have made the tragic situation in Haiti even worse. Reports from the Matènwa Community Learning Center (MCLC) state that Matènwa is experiencing an even worse shortage of supplies partly due to the cost of rice increasing by over twenty percent and the cost of flour increasing by over fifty percent. The MCLC has also attributed the deteriorated situation in Matènwa to the lack of connection to the mainland. One of the most important reasons for the enduring poverty and scarcity in Haiti has been in the past the failure of the Haitian government, attributable to corruption and often coming to power through violence.

As seen by the global humanitarian response to the earthquake in Haiti, there is a heartfelt sense of obligation to help the unfortunate in this nation, which in the past has been abused and exploited by the international powers. However, the plight of isolated villages such as Matènwa is not well known and a permanent solution will take more than just humanitarian aid. Long term sustainable solutions must be formulated, and must be done in such a way that it creates the opportunity for self-sustainability in small communities such as Matènwa. The MCLC and other NGOs have already started to work with Matènwa to help them reach self-sustainability. They are being taught how to farm, and are actively working on the reforestation of the devastated forests around the village. Among all these important projects and goals, providing clean drinking water must be considered a crucial need. A single water collecting cistern has been built, but it is not enough for the entire community. To help Matènwa reach their goals of self-sustainably and recovery of their natural resources, the tools and techniques of Participatory Rural Appraisal (PRA) would be useful in mobilizing community participation.

Research &Analysis Chapter

Rainfall Harvesting Technology can make the utilization of rainwater a valuable and essential water resource in most developing countries that have abundant precipitation but lack a reliable water supply and/or a fresh water source. As a village on an island whose resources have been severely exploited, Matènwa is faced with several issues including the difficulty of collecting water from the few available sources, as well as a general problem of water shortage rising from the meteorological consequences of deforestation. The low ability of soil to retain water that comes as a consequence of deforestation leads to substantial waste and loss of potential drinkable water from rain. These factors have convinced us that the application of Rainfall Harvesting Technology to tackle water shortage issues is the best way to address the problem in Matènwa. In fact, Rainfall Harvesting Technology will be beneficial because 1) most of the ground water sources have been contaminated and are often distant from houses, while rainwater is available anywhere throughout the village. 2) Rainfall is adequate, ranging from 1,200mm to 2,000mm per year. And 3) improved water quality is urgently needed to control the spread of diseases. Research suggests that the process of implementing Rainfall Harvesting Technology will be significantly simplified because 1) the gutter that composes these systems has already been employed on some houses in Matènwa. 2) Low cost will make the application approachable for most local families. And 3) little maintenance or supervision is required to adapt a gutter for rainwater collection for drinking purposes.

However, in order to implement such system successfully and efficiently, a plan that only considers the steps necessary to physically construct the system is nowhere near enough.

Social factors related to the empowerment of the community to enhance collective efforts have to be investigated from the very beginning of getting everyone to agree upon doing a rainwater harvesting plan to the final necessities of maintaining the finished system. This Research and Analysis chapter will demonstrate why we recommend a Rainfall Harvesting System to solve the technical problem and what needs to be understood to encourage collective commitment toward constructing such a system.

General Technical Description

A rooftop rainwater system is usually composed of four basic components: a collection area, a conveyance system, storage facilities and purification devices. The schematic of a typical rooftop rainwater system is shown in Figure 11.

The collection area refers to the land surface or roof of a house or a building (catchment and collection of rainwater will be discussed later in this chapter). The roof should have sufficient inclination, to avoid standing water, and be strong and large enough to bear peak flows. In order to construct these systems for each individual household and to determine the materials to be used, we need to know the roof area of the houses and the quality of the rainwater after it goes through the gutters.

The conveyance system is generally designed to transfer the rainwater caught on the rooftops to a storage tank by using pipes or gutters connected to the rooftop areas. Given the fact that distinct rainfall distribution varies by seasons in Haiti, considerations should be taken, during the transitional seasons from dry to rainy, to avoid dirt and debris produced from the rooftop from washing into the storage tank pipes.

Storage devices are required in the rainwater harvesting system to hold the water for future purification and use. When selecting the storage devices, caution should be taken to prevent contamination from human, natural and other environmental pollutants.

Purification devices are used to sanitize the rainwater to provide clean water that meets human health standards. In our case, a ceramic filter is being recommended because of cost, effectiveness and ease of maintenance.

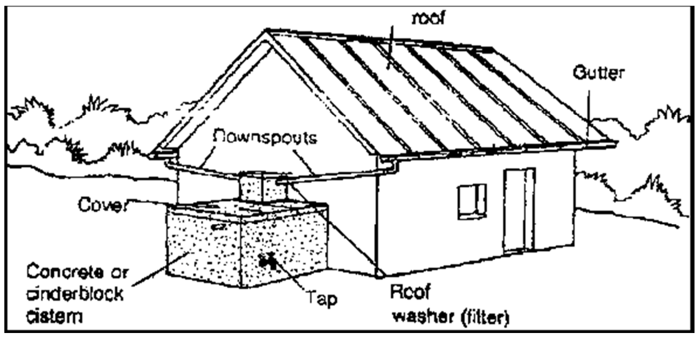

Figure 11 – Schematic of a Typical Rooftop Rainwater System

Rainwater Catchment

Water has to be captured before any collection, storage and purification process can begin. There are basically four main options of rainwater catchment: Single Roof water Collection, Large Roof Water Collection Systems, Land Surface Catchments and Storm Water Collection Catchments.

Single Roof Water Collection system[2] is the most basic form of this technology built on the roof of each house. Rainwater is caught in simple vessels at the edge of the roof, which is a gutter system that is, after falling on the roof, rainwater drains into gutters and then into pipes, as seen in Figure 12. We contacted Zoe Wolf, a student from Northeastern University who has

[2] Large Roof Water Collection Systems are very similar to the single roof collection systems but they're mostly designed for large and high-rise buildings. Since the village doesn't have any buildings on which this system could be implemented, this option will not be addressed further.

been doing her school internship on Matènwa, and she told us that some families have already built their own gutter systems to collect rainwater, but those systems lack the precision and efficiency to provide sufficient healthy water. This method of catchment is very promising since it will largely reduce the complexity of construction and is a feasible option to collect water at low cost. More importantly, villagers will not face the necessity of having to walk for hours to obtain water. We also contacted co-director of the Matènwa Community Learning Center, Christine Low, and found out that typical areas for the houses on Matènwa are between 160 and 288 square feet.

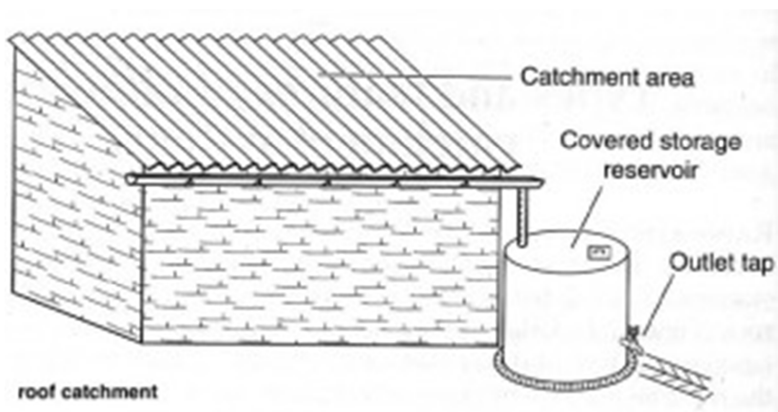

Figure 12 – Roof Catchment System (mercy-walk.org)

Land Surface Catchment is mainly designed to improve the runoff capability of the land surface including collecting water in drain pipes and storing the collected water in underground storage. Figure 13 shows the process of land surface catchment systems. One disadvantage of this system is that there is a possibility of high rates of water loss due to infiltration into the ground and the marginal quality of the water collected, which makes Land Surface Catchment a possible solution for agricultural use because of the marginal quality of the collected water. Moreover, for the purposes of this project, which is based on finding the least expensive solution to the problem, underground water storage costs more than regular above ground storage because of construction excavation expenses while a cistern will utilize less construction material , which will be the less expensive in total.

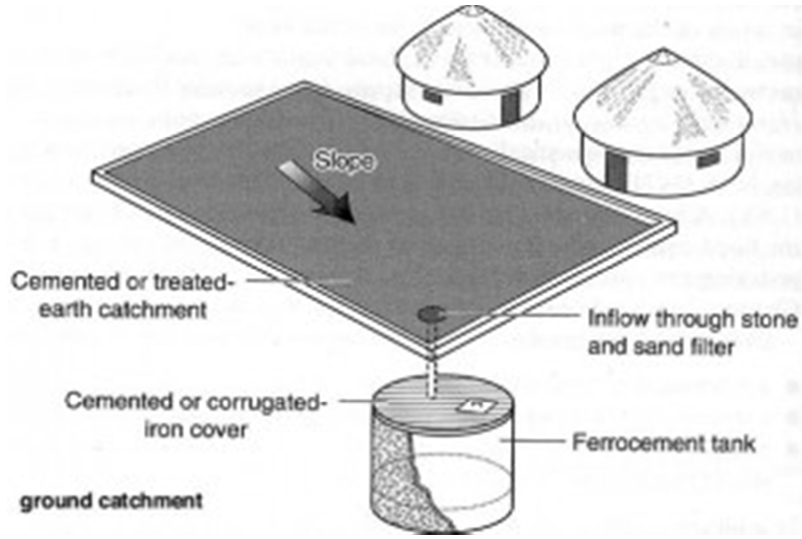

Figure 13 – Land Surface Catchment System (mercy-walk.org)

The Storm Water Collection method is used to catch the rain or melted snow that runs off surfaces such as rooftops and paved streets and flows into a local stream or lake. But these surfaces need to be kept clean because otherwise the water will become polluted as it runs off these surfaces. If the water gets polluted, a draining system would be necessary to let the polluted water flow out of the storage system, and at its current stage of development, installation of a sewage system in Matènwa is virtually impossible. Nevertheless, depending on the quality of storm water, it could be used for agriculture but, similarly to the Land Surface Catchment method, an underground storage would be needed raising therefore the cost of the whole system.

Gutters

Gutters are the mechanisms attached to the end of the roofs with downward slopes to let the water escape through leaders and prevent water from pooling on rooftops. They are usually made of aluminum, steel and vinyl (also called PVC). The price installed aluminum gutters is about $5 to $9 per foot. Aluminum is relatively durable and will never rust but its disadvantages outweigh its advantages: Aluminum gutters can easily be deformed from such things as falling branches and need more attention to be maintained. They are susceptible to corrosion if in contact with certain materials like copper or steel. They can often cause leaking problems too because Aluminum will contract in winter and expand in summer, which results in a joint crack and causes leaking. Steel gutters are stronger than aluminum and can stand up to falling branches or other blows. But steel is very easy to rust, bend and lose shape when distorted. Additionally, steel gutters are very heavy and are hard to install. They cost from $4 to $8 per foot installed. Vinyl (PVC) gutters are considered to be the best solution in terms of cost, strength, flexibility, installation and durability. The general design is shown below in Figure 14. They cost over 10% less than steel or aluminum gutters, approximately from $0.3 to $0.5 per foot installed, which is a necessary consideration in a developing nation like Haiti. Originally made from plastic, PVC gutters are water resistant and will not corrode or rust. Comparing similar shapes and sizes, plastic gutters perform better than metal gutters. For example, when loaded by ladders or other heavy loads, plastic gutters will get less damage than metals gutters would. PVC gutters are very flexible too and will keep their shape even when they are distorted or bowed. The blemishes caused by bending, denting and twisting effects are invisible to the naked eye. Unlike the other types of gutters, PVC gutters are also very easy to install. They are light and able to be snapped together very easily and don't require any professional skills, which lessens concerns about complicated construction skills that are not accessible to the people of Matènwa. Bamboo can be an alternative for vinyl if some families choose not to spend any money on gutters, but bamboo is very easily attacked by termites and bacteria. It also needs to grow for 3 to 7 years to become ready for cultivation, and after 5 to 8 years fungal mold can cause the culm to collapse and decay. Another WPI project team has researched the possibilities of using bamboo to make pipes/gutters, and their results are similar to our conclusions that bamboo can only be a temporary solution because of its long growth and fast decaying times (Pierre David).

There are examples of rainwater collection projects designed for schools in Karnataka (India), where PVC gutters were applied to transfer the water from the roof to a storage tank, and these are useful to illustrate what might be done in Matènwa. Figure 15 was taken in one of the schools in Karnataka.

Figure 14 – Clean PVC gutter to catch rainwater

Figure 15 – Gutter systems installed in a school in Karnataka

The Government of Karnataka, through the Rural Development and Panchayath Raj department, launched this rooftop rainwater harvesting program for 23,683 schools for the whole state. This rooftop rainwater harvesting system seeks to provide a reliable source for several purposes such as bathroom flushing, cooking, personal washing and hygiene needs, and drinking after it is purified, with the expectation of supplying each student with 0.40 gallons (1.5 liters) of drinking water. This project was already approved and is implemented by the Engineering Department of various local governments and by the District Nirmithi Kendra.

Maintenance of Rainwater Catchment System

Maintenance generally refers to the cleaning of all the components in the system and regular inspection, particularly the roofing, the conveyance system, the storage devices and purification filters in the proposed design. The cleaning is usually limited to removing dirt, leaves and other impurity and should be done before and during each rainy season every year.

Regular inspection is required all along to make sure everything works appropriately and guarantees the quality of the water provided.

There is a similar project done in Tanzania in 2008, where a rooftop harvesting system was successfully constructed and has been well-maintained so far. Taking their experience as a reference, our group came up with a preliminary plan to maintain the rooftop rainwater harvesting proposed for Matènwa. As will be discussed later, various work projects need to be assigned to the community to maintain a rooftop water catchment system, and one chore is cleaning the roofs before the rainy season starts.

Matènwa only has significant rain in particular months, therefore precautions have to be taken to make sure the first water, which initially washes the gutters, doesn't go into the storage tank and affect the water quality. The solution to this problem is to direct the first-flush water that goes in the downpipes to somewhere else by adding a directing faucet at the end of the pipes. Table 2 summarizes some recommendations on what to do before, during and after the rainy seasons, in order to maintain the collection system clean.

Table 2 - Recommendations to Maintain Rainwater Collection System

To do before the rain starts	To do during the rainy season	To do at the end of the rainy season
• Clean the roof • Clean the gutter • Clean all kinds of pipes • Clean purification devices	• Empty the downpipe after each rainfall • Check and clean the roof • Check and clean the gutter • Check and clean all kinds of pipes • Check and clean purification devices	• Make sure no animals, insects, or any other dirty material entered the system

However, even if there is a detailed procedure established to maintain the system, it is also important for people to feel responsible and take the initiative to keep up with maintenance. Some of the maintenance activities are necessary all the time and require teamwork effort to achieve this goal since it is impossible for one person to watch the system every single second. Thus, social factors have to be considered as well in terms of how to encourage community participation and make everyone feel responsible for maintaining an effective and hygienic system, which will be explained in a later section.

Rainwater Catchment in Matènwa

In order to know how many gallons of rainwater per month could be collected by every roof in Matènwa, we need to know two different factors: the annual rainfall and the area of the houses. According to Christine Low, typical roof square footages for the houses of Matènwa average around 160 and 288 square feet (10' x 16' and 12' x 24', respectively), and it is known that La Gonâve gets an annual rainfall of approximately 47.24 inches or 1.2 meters (climatetemp.info).

Table 3 – Simplified Table of Rational Runoff Coefficients (LMNO Engineering)

Ground Cover	Runoff Coefficient (c)	Ground Cover	Runoff Coefficient (c)
Lawns	0.05 - 0.35	Residential areas	0.3 - 0.75
Forest	0.05 - 0.25	Business areas	0.5 - 0.95
Cultivated land	0.08 - 0.41	Industrial areas	0.5 - 0.9
Meadow	0.1 - 0.5	Asphalt streets	0.7 - 0.95
Parks, cemeteries	0.1 - 0.25	Brick streets	0.7 - 0.85
Unimproved areas	0.1 - 0.3	Roofs	0.75 - 0.95
Pasture	0.12 - 0.62	Concrete streets	0.7 - 0.95

However, there will also be losses due to the water splashing off the roof, water absorption and other factors. To take these factors into account we used the Simplified Table of Rational Runoff Coefficients (Table 3) to determine the appropriate runoff coefficient. To come to a closer estimate we chose the mean value of the range provided under "roofs" (c = 0.85).

After considering all the factors previously mentioned, we determined the number of gallons per months that would be collected. The results are shown below while the calculations are shown in Appendix B.

Table 4 – Volume of Caught Rainwater

Roof Size		Number	Caught Water (Ideally)		Caught Water (Realistic)
Length (ft.)	Width (ft.)	of Rooms	(cu ft.)	(gallons/month)	(gallons/month)
10	16	2	630.4	392.95	334.01
12	24	4	1134.72	707.31	601.21

In addition, studies have shown the potential for pollutants leaking into the environment from roofing materials that may occur at any point in the lifetime of the roof, but it is thought that the periods of concern for pollutant leakage are during the early and late life of the roof. During the early life, some contaminants are washed off, and in the late life other contaminants are released due to the degradation of the material (HarvestH2O). Also, another study conducted at Penn State (Harrisburg) indicated the magnitude in which different roofing materials can pollute the water that is being harvested (See Figure 16 and Figure 17). From these box-and-whisker plots, galvanized roofs provide a very low concentration of Copper, Nitrate, and Phosphorous, but they contribute a high concentration of Zinc (around 6 mg/L), one milligram of Zinc above acceptable levels. It should be noted, however, that the presence of Zinc in drinking water does not bring any health concern, but it may affect the taste of the water by adding a metallic flavor (United States Environmental Protection Agency).

On the other hand, rainwater collected from rooftops will provide a higher quality water source than the surrounding surface waters and because there is not intense industrial activity in Matènwa, rainwater will not be exposed to toxic chemicals. Furthermore, a regular maintenance of the system (by repeated flushing) will reduce any possible chemical deposition (Dennis J. Lye, 2009).

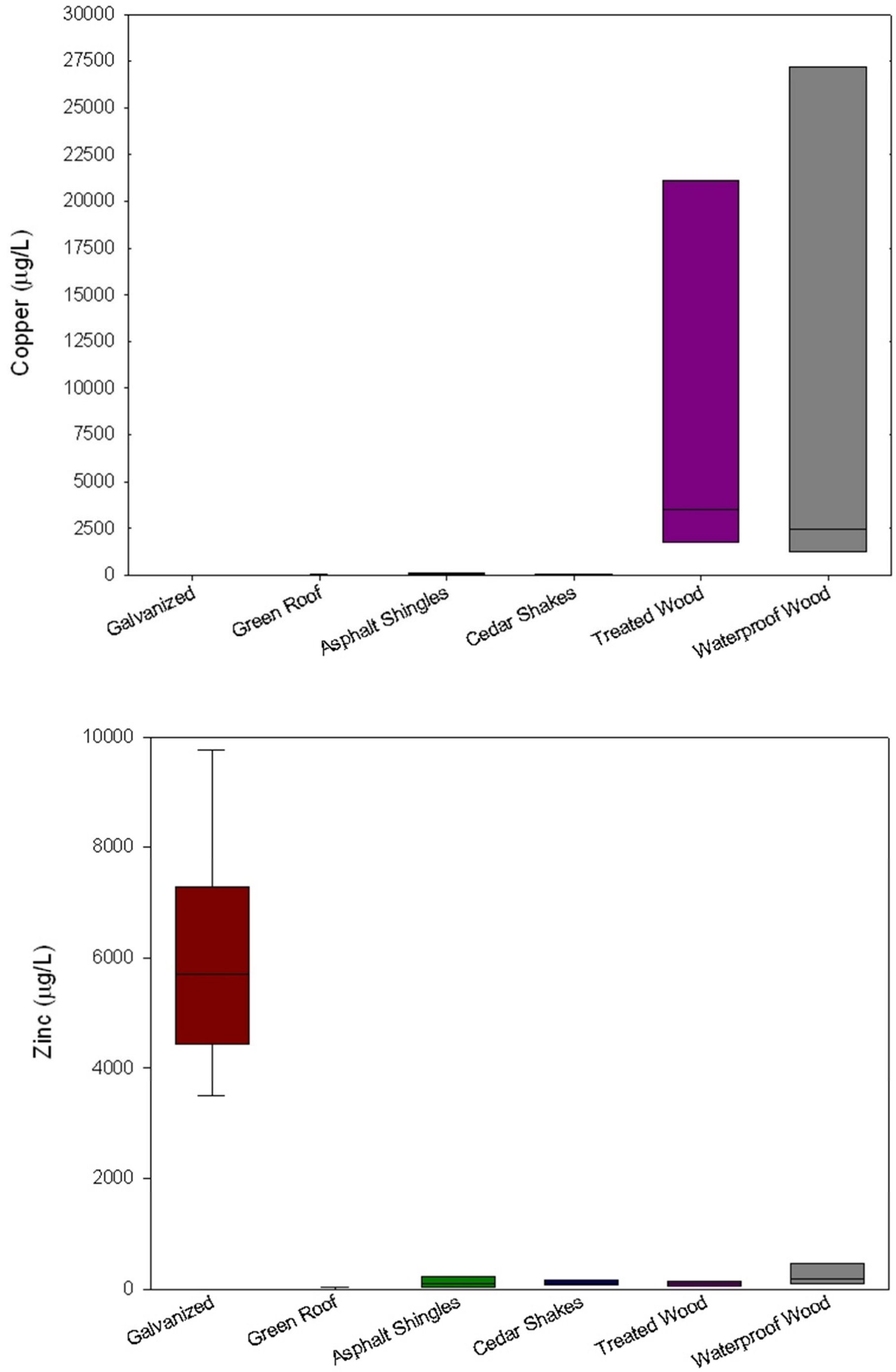

Figure 16 – Copper (top) and Zinc (bottom) concentrations for several roofing materials © Shirley E. Clark, 2008 (See below for explanation on how to read the graph)

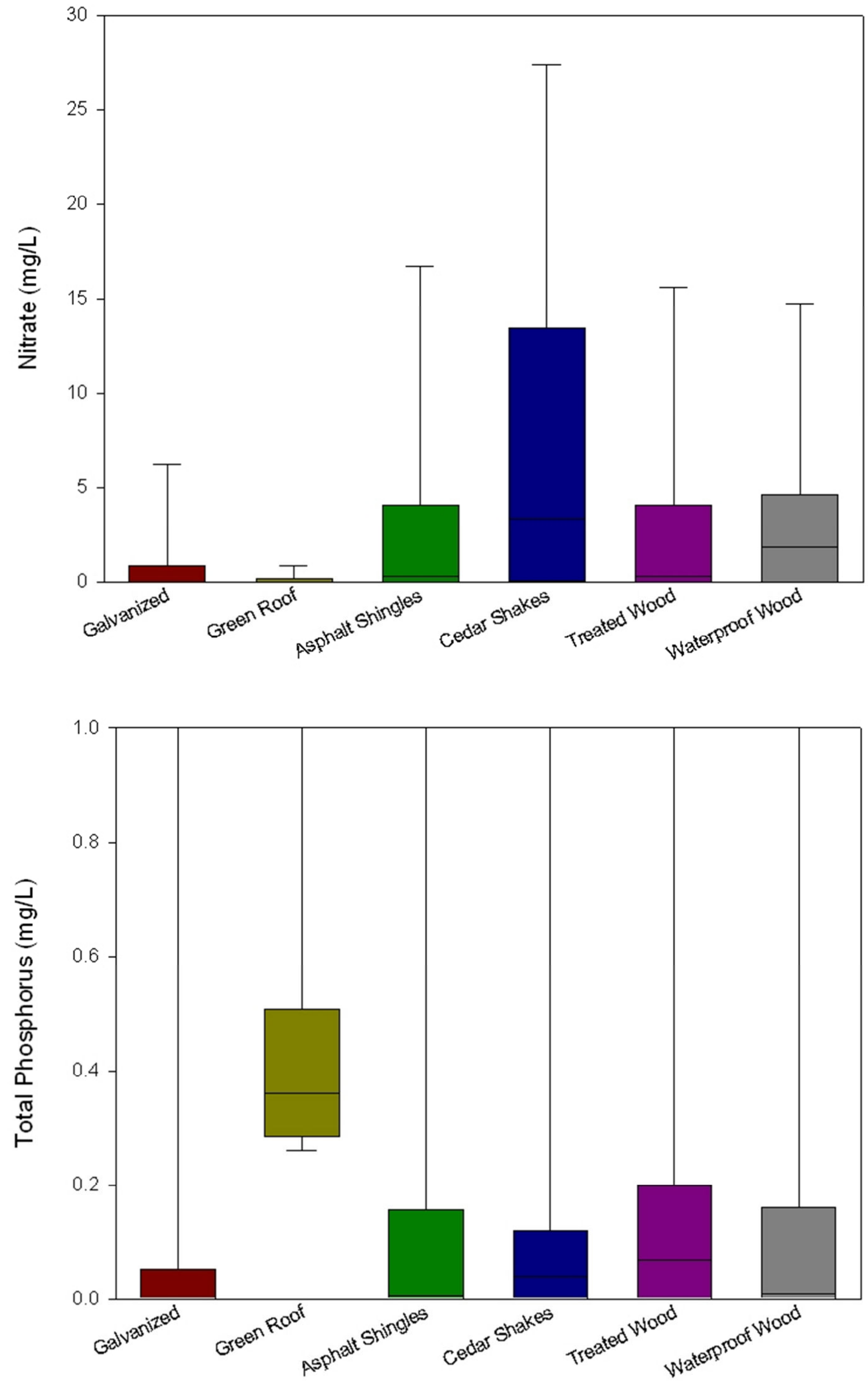

Figure 17 – Nitrate (top) and Total Phosphorous (bottom) concentrations for several roofing materials © Shirley E. Clark, 2008[3]

[3] The line in the middle of the box represents the median of the sample being studied. The lower and upper edges of the box represent the lower and upper quartiles, respectively. And the lower and upper lines outside of the box represent the smallest and largest observation in the sample, respectively.

Table 5 – Secondary Maximum Contaminant Levels (MCL) (USA EPA)

Contaminant	Secondary MCL	Noticeable Effects above the Secondary MCL
Aluminum	0.05 to 0.2 mg/L*	Colored water
Chloride	250 mg/L	Salty taste
Color	15 color units	Visible tint
Copper	1.0 mg/L	Metallic taste; blue-green staining
Corrosivity	Non-corrosive	Metallic taste; corroded pipes/fixtures staining
Fluoride	2.0 mg/L	Tooth discoloration
Foaming agents	0.5 mg/L	Frothy, cloudy; bitter taste; odor
Iron	0.3 mg/L	Rusty color; sediment; metallic taste; reddish or orange staining
Manganese	0.05 mg/L	Black to brown color; black staining; bitter metallic taste
Odor	3 TON (Threshold Odor Number)	"rotten-egg", musty or chemical smell
pH	6.5 – 8.5	*Low pH:* bitter metallic taste; corrosion *High pH:* slippery feel; soda taste; deposits
Silver	0.1 mg/L	Skin discoloration
Sulfate	250 mg/L	Salty taste
Total Dissolved Solid (TDS)	500 mg/L	Hardness; deposits; colored water; staining; salty taste
Zinc	5 mg/L	Metallic taste
* *mg/L is milligram of substance per litter of water*		

Water Storage

The water ultimately will be stored in storage tanks or cisterns, the design of which is determined by the water needed for healthy living and the type of construction material used to prevent contamination from nature. The upper limit size of the storage system is dependent on the product of the average precipitation and the roof area. Generally, the roof area is slightly larger than the actual area of each house. Through our talks with the people who have been working at Matènwa, there are generally two sizes of houses, described above in Table 4.

According to the World Health Organization, as indicated by Table 6, a minimum of 7.5 liters (1.98 gallons) per day will meet the requirements of most people under most conditions. Almost 15 liters (4 gallons) per day is required in emergency situation while 20 liters (5.28 gallons) per day is safe to take care of basic food and hygiene needs.

Table 6 – Simplified Table of basic survival water needs

Simplified table of basic survival water needs		
Survival needs: water intake (drinking and food)	2.5-3 litres per day	Depends on: the climate and individual physiology
Basic hygiene practices	2-6 litres per day	Depends on: social and cultural norms
Basic cooking needs	3-6 litres per day	Depends on: food type, social as well as cultural norms
Total basic water needs	7.5-15 litres per day	

Given the average family size for each kind of house, as well as the amount of water needed per person to live under healthy standards, we calculated the monthly amount of water needed in each size house. These results are shown in Table 7 and their calculations can be found in Appendix C.

Table 7 – Amount of water needed for healthy living standards

House Area (sq. ft.)	Average Family Size	Water needed per house (gallons)	Water Needed per month (gallons/month)
160	4	21.12	633.60
288	6	31.68	950.40

Choosing between an underground cistern and an above ground tank for water storage is an important consideration depending on whether it is a storage system for each household or a central system for the whole village. In comparing the two storage systems, we found that a storage system for each household is a better solution for Matènwa considering price, maintenance and conveniences.

For a central storage system, a large underground tank would be required to maintain the water and, according to Zoe Wolf, the separation of houses and the uneven land in

Matènwa makes traveling between homes extremely arduous. Even if a central tank would make the process of getting water more convenient for some residents of Matènwa, the cost of a 3,000 gallon, fiberglass underground water cistern (Horsemansdepot.com) would be excessive at $6,600. In addition, the costs of installation and maintenance of a central system would be far out of reach for the residents of Matènwa.

A storage system for individual household seems to be a much better solution giving the current status of Matènwa. Using this system, a much smaller container can be used for each individual household, which will reduce the price and problems of maintenance. Since the water will be stored near each house, the villagers will not need to travel any distance to obtain the collected rainwater. The rainwater storage vessels are often constructed from concrete, galvanized steel or Polyethylene (Using Rainwater for Your Home). The rainwater storage vessels should be able to block sunlight, which will help decrease the algal blooms. To prevent the contaminants, such as insects, debris and dirt, rainwater storage vessels are often covered. The vessels contains anywhere from 400 liters to millions of liters for huge water storage. According to the article "Using Rainwater Tanks for Your Home," even an inch of rain on a roof measuring about 93 square meters can create run-off for more than 620 gallons of water.

Rainwater storage vessels materials come in a wide range of materials and size. Selecting a best material depends on a lot of factors, such as the location of the water cistern, volume of the water it holds, temperature and weather patterns, cost, sustainable considerations and many other factors.

Water Storage Vessel Sizing and Materials

Traditionally the water storage vessel is the most costly aspect of the system and it represents the largest capital investment. Since concrete is very hard to deliver to Matènwa, it can be very expensive. For this reason it is important that the vessel that we pick is carefully designed to minimize the cost as well as optimizing storage capacity. To be able to create maximum efficiency we must calculate the storage needs of the community, and then we can apply the information to our selection of a way that can minimize overall cost. To calculate the amount of water storage capacity, we developed a relationship between consumption and the length of the dry season: $T = D * L$, where $D = C * F$.

T = Total storage needed

D = Total Daily consumption

L = Average length of the longest dry season

C = Daily consumption of water per person

F = Average number of family members

The World Health Organization advises that an average person should consume 5.28 gallons (20 liters) of water a day. According to United Nations and the CIA, a Haitian women has on average 4 to 4.5 children in her lifetime, thus we will estimate the average family size to be 6 people. The longest dry season in La Gonâve stretches between the months of November to March. This 5 month stretch accounts for 151 days. Therefore,

$D = 5.28\ gallons * 6\ members = 31.5\ gallons$, and

$T = 31.5\ gallons * 151\ days = 4{,}756.5\ gallons = 18{,}120\ liters.$

We can now utilize this data to determine not only what is the best water storage vessel for Matènwa community, but also use it to make recommendations in the design and construction of the water catchment and storage facility.

There are three main materials used for storage vessels—bamboo, ferrocement and polyethylene. Bamboo has been a hot topic under discussion by advocates of appropriate technology because it is very abundant in tropical areas like Haiti and would be an excellent low-cost alternative if proved to be effective. However, it faces the problem of being easily attacked by termites and bacteria. From 1986 and 1993, Thailand and Indonesia have built 50,000 bamboo tanks but they ended up being abandoned by the 1980s due to problems of deterioration.

The second option is ferrocement vessels (Figure 18), which consist of a cement mortar reinforced with layers of wire mesh. They are usually cost effective to build and require little skilled labor, which could be done easily and efficiently by encouraging community participation. They also bend very well and are able to withstand shock. In general, ferrocement vessels are only needed whenever the storage volume exceeds 264.17 gallons (1,000 liters), which works perfect for the estimated water need in Matènwa of 951 gallons (3,600 liters) per month.

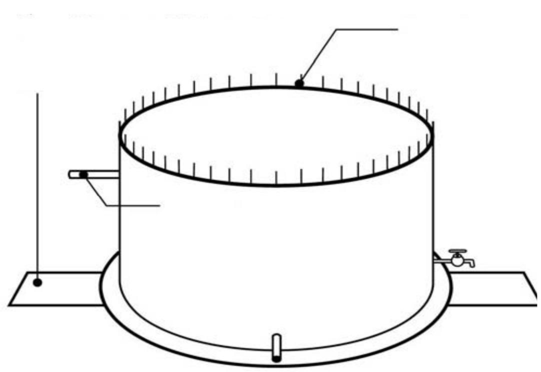

Figure 18 – Ferrocement Tank

The Polyethylene tank is another common type being used (Figure 19). Specially designed and reinforced vessels can resist soil expansion and contraction very well. They are relatively light and long lasting but the fittings are not very tight and have to be checked constantly for leakage problem. This material isn't realistic in Matènwa because it requires the constant supervision of experts as well as professional skills for its maintenance, which are not currently accessible on La Gonâve. In addition, there are other disadvantages including the disposal of the units once their service life is over, not to mention the cost of shipping the units to Haiti from the United States.

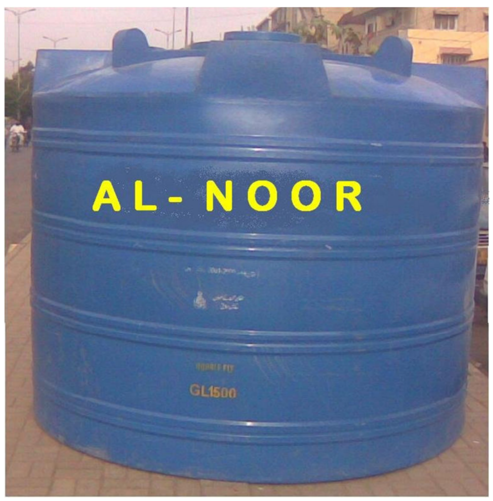

Figure 19 – Plastic Water Tank

Water Tanks and Cisterns

Sanitary drinking water shortage is a problem that is not only unique to Matènwa. Over history civilizations have been devising different ways to collect and store water, as a means to prevent water shortages. These systems have ranged from simple clay pots catching water, to complex computer controlled systems that control the collection and storage of water. All these systems are known as a rain water harvesting systems (RWH). The complexity of the systems that are being created and built in several poverty stricken and water deprived communities, range from simple to complex. In analyzing other regions similar to Matènwa, we have noticed that most communities use a basic system of rooftop collection system that channels water into a collection vessel such as the Ferrocement tank used in Ruganzu Village, Tanzania show in Figure 20.

Figure 20 – Ferrocement tank in Ruganzu Village, Tanzania. (Photo credit: DTU)
(This is a depiction of a larger water tank. The water vessels that are utilized to store water can range from recycled materials or clay pots, to manmade storage systems)

Before choosing which materials would be best suited for the water storage vessel, we must determine whether a water tank or a water cistern would be the most viable option for the completion and long term success of the Matènwa rain water harvesting system. A water tank is built above ground, while the water cistern is built so it remains underground. Table 8 shows several pros and cons to each storage unit, which we must weight against each other.

The maximum size for a water storage vessel typically ranges between 20 and 30 cubic meters. In the case of Matènwa, space is required to safely store the maximum of approximately 601.21 gallons of storage space to safely be able to store the maximum amount of rainwater that could be collected in a month. The system we propose would be relatively large, so factors concerning structural integrity, location, materials used, exposure to natural elements, potential dangers, and availability of a labor force will play the leading role in our final decision.

Table 8 – Tanks vs. cisterns (pros and cons)

	Tank	Cistern
Pros	• Above ground structure allows easy inspection for leakages • Many existing designs to choose from • Can be easily purchased 'off-the-shelf' • Can be manufactured from a wide variety of materials • Easy to construct from traditional materials • Water extraction can be by gravity in many cases • Can be raised above ground level to increase water pressure	• Generally cheaper due to lower material requirements • Not vulnerable to water loss by tap left open • Require little or no space above ground • Unobtrusive • Surrounding ground gives support allowing lower wall thickness, and thus lower costs
Cons	• Require space • Generally more expensive • More easily damaged • Prone to attack from weather • Failure can be dangerous	• Water extraction is more problematic, often requiring a pump • Leaks are more difficult to detect • Contamination of the cistern from groundwater is more common • Tree roots can damage the structure • There is danger to children and small animals if the cistern is left uncovered • Flotation of the cistern may occur if groundwater level is high and the cistern is empty. • Heavy vehicles driving over a cistern can cause damage

Water Tanks

Water tanks are built above ground, and can be built utilizing a wide variety of materials, ranging from concrete and steel to burlap bags and clay pots. Considering the separation of houses in Matènwa, it would require water tanks for each household; therefore we would need to utilize appropriate materials to insure the structural integrity of the storage unit.

A water tank utilizes gravity to send the water to filtration points and then on to pipes that supply users with clean water. The use of gravity will eliminate the need for pumps, while maintaining water pressure. The above ground water tank remains visible, which allows the users to monitor and survey it to detect damage or problems, allowing for pre-emptive care and maintenance. The above ground water tank has many safety flaws and has a higher cost associated with it, but its utilization of gravity and visual monitoring still makes it a viable candidate for use.

Water Cisterns

Water cisterns are built underground, and traditionally use a specific range of materials. The most common materials are cement, sand, and steel rebar or wire. These might seem like expensive materials, but they are common materials when building an above ground fibro-cement water tank. The water cistern has a cost advantage since it is built underground, the surrounding earth acts as a natural support system, and allows the cistern to have better structural integrity while utilizing less material. This greatly reduces the cost associated with construction because unskilled labor costs for excavation are relatively cheap in the developing world. Sri Lanka has built underground cisterns in its impoverished regions, and has noted the cost efficiency. There is also a safety advantage; while it is buried underground, the earth supplies a buffer protecting people from any unexpected damages that would potentially cause injuries. Although the cistern is underground and out of the way, it is not available for visual monitoring. Leaks can occur without anyone knowing and this unknown drainage could cause water sources to be depleted quicker than expected during the dry seasons. Pumps will however, be needed to play the vital role in the transfer of water. This would have been a concern, but a homemade hand pump using PVC pipes and recycled rubber has allowed for a low cost (8.00USD) solution can be built. There are also environmental concerns; tree roots can cause damage over the long term, but the area around Matènwa is deforested so at this point there is no concern about root damage. However, the residents of Matènwa will need to be educated about planting trees close to water cisterns and will have to be advised to allow for a wide berth to be preserved around the unit. The water cistern has several disadvantages, but several of them can be prevented with proper planning and education. Its advantages far out weight the potentially long term disadvantages.

Cisterns Case Studies

Table 8 above shows the pros and cons of cistern and tank. Now that we understand the pros and cons of water tank and cistern, it is clear that cistern is a better choice for people in Matènwa. Through our research, we have found several case studies throughout the world that have chosen cistern as the storage vessel for a rainwater harvesting system. One case is the Cement Mortar Jar which is originally developed in Thailand. The Cement Mortar Jar is relatively strong, it is easy to construct in varies sizes and it has been commonly used in rural places in Southeast Asian. According to the Technical Information Online, the detail construction for this type of cistern is:

- To make the bottom of the tank, mark out a circle on the ground of 1m diameter and place ½ bricks or other suitable material around its circumference to act as a formwork.
- Spread paper or plastic sheeting on the ground within the circle to stop the mortar sticking. Mix a 1:3 cement: sand mortar and spread within the circle to a depth of 15mm.

- When the bottom plate has set, place the sacking bag narrow end down on the plate and begin filling it with sand, sawdust or rice husks. Make sure that the mortar base sticks out from under the sack and tuck the edges of the sacking under the filling material, so that the weight of the filling holds the sacking on the plate.
- Fill the sack, fold the top and tie it closed. Then fold and smooth the sack into a regular shape. Make a circular ring from wood or cement mortar and place this on top as the formwork for the opening in the top of the jar.
- Spray the sacking with water until it is thoroughly wet, then plaster on the first layer of cement mortar to a thickness of up to 10mm.
- Plaster on the second 5 - 7mm layer in the same manner as the first, checking the thickness by pushing a nail in. Build up any thin spots.
- Remove the sack and its contents 24hrs after the plastering is completed. Repair any defects with mortar and paint the inside of the jar with cement slurry. Then cure the jar for 2 weeks protecting it from sun and wind under damp sacking.

The recent cistern build in Tanzania shows that by pairing up one skilled worker with one unskilled worker for the construction is enough to build the system in weeks. If we can expand that ratio to one skilled person and two unskilled people, the construction time can be shortened. In case of Matènwa, we can have the skilled constructor teach the unskilled ones so the construction skill can be widely spread throughout the village.

Water Tank and Cistern Conclusion

Both the water tank and cistern has its advantages and its disadvantages. Through our research we have determined that the advantages of the water cistern far outweigh its disadvantages, compared to the disadvantages and advantages of the water tank. The water cistern has a key advantage in two areas, less amounts of materials required, and the low cost for construction. Both options are exposed to some natural hazards. The water tank is exposed to environmental hazards, which cannot be controlled. The water cistern on the other hand has vegetation hazards, which with proper education and planning can be prevented. The water tank will utilize gravity to move water out of the tank; this will limit the amount of components required for the completion of construction. The water cistern will require additional components to function; it will need a pump to move the water out of the cistern. We have found a low cost pump using PVC pipes and recycled rubber for the cistern, limiting the gravitational advantage the water tank has. The single advantage that the water tank has is its ability to be visually monitored and pre-emotively repaired. This single advantage is not enough for us to recommended using it, and thus we strongly advise the use of water cisterns.

Purification and Filtration

Although rainwater is one of the sources of water that can be used to reduce the water problem in Matènwa, the water should be purified after it has been collected and prior to using it. The use of ceramic water filters (CWF) is an effective and inexpensive method that has been used in many countries for several centuries (García Márquez, 1999, p109-110). Like most filtration methods, ceramic filters rely on the small pore size of ceramic material to filter dirt, debris, and bacteria out of water. In addition to natural filtration, many ceramic water filters are treated with silver. The silver is in a form that will not leach away and it helps to kill or incapacitate bacteria and prevent the growth of mold and algae in the body of the filter. The silver-containing alterations are either painted onto the surface of the ceramic before or after firing, or applied to filter elements in other ways. Silver nitrate solutions or colloidal suspensions of silver are most often used for this purpose.

Ceramic filters are commonly used throughout the world, in both developed and developing countries. In developed countries such as the United States the use of ceramic filters has been improved with advanced technology (Lantagne 2001a, 2001b). The filters are made to exact specifications that improve the quality of filtration, but as a result, there is an increase in the cost. In developing countries, the use of ceramic filter is a lot simpler, making it low in cost; however the effectiveness of the filter is compromised. The most common example of a low cost ceramic filter is in the form of a pot. This method includes the use of the filter pot and the storage receptacle. To use ceramic filters, families fill the top ceramic filter pot itself with water, which flows through the pores of the ceramic filter or filters into the storage receptacle.

There are many advantages as well as a few disadvantages that come with the use of a ceramic filter in Matènwa. As mentioned before, the simplicity of a ceramic filter would make it ideal for many households in Matènwa. Ceramic filters have proven to be effective in removing most bacteria as well as a few protozoa. The filters could also help reduce the cases of cholera depending on the production quality of the filter. Most ceramic filters are effective at removing the larger protozoa and bacterial organisms that cause diarrheal disease.

However although these filters work against bacteria, they fail at removing the smaller viral organisms. Also there is a high risk of bacterial contamination when filters are poorly maintained or are of just poor-quality, or if the receptacle is contaminated at the household level. These filters lack residual protection, so it is important that users be trained to properly care for the ceramic filter and receptacle. This training would need to include how to properly clean the filters, as well how to properly replace certain parts.

A PhD Graduate student of the University of North Carolina at Chapel Hill did a similar water catchment project involving ceramic filters in Cambodia ("Effectiveness of Ceramic Filtration for Drinking Water Treatment in Cambodia"). This project used three types of ceramic water purifiers: Ceramic Water Purifier with AgNO3 (CWP1), A Ceramic Water Purifier modified by adding FeOOH (CWP2), and a Ceramic Water Purifier without AgNO3 or FeOOH (CWP3). (Brown 84-109). The results of the experiments can be seen in the following figures and tables. (Brown 84)

Table 9 – Brown 86

Filter	*Microbe*	*Challenge water*	*n*[a]	*V*[b] *(l)*	*Mean influent (log_{10} units)*[c]	*Mean filtrate (log_{10} units)*[d]	*LRV mean*[e]	*95% CI*	*LRV std dev*	*LRV variance*
CWP1	*E. coli*	Rain water (A)	34	660	4.6	2.3	2.3	2.0-2.6	0.83	0.69
		Surface water (B)	34	660	5.1	2.7	2.4	2.1-2.6	0.72	0.51
	MS2	Rain water (A)	17	660	6.9	5.6	1.3	0.47-2.1	1.6	2.6
		Surface water (B)	17	660	6.6	4.9	1.7	1.1-2.3	1.2	1.4
CWP2	*E. coli*	Rain water (A)	34	660	4.6	2.6	2.1	1.8-2.3	0.77	0.59
		Surface water (B)	34	660	5.1	2.9	2.2	1.9-2.5	0.79	0.62
	MS2	Rain water (A)	17	660	6.9	5.4	1.4	0.73-2.0	1.3	1.6
		Surface water (B)	17	660	6.6	5.4	1.3	0.82-1.8	0.97	0.93
CWP3	*E. coli*	Rain water (A)	68	1340	4.6	2.9	1.8	1.5-2.0	1.0	1.0
		Surface water (B)	68	1340	5.1	2.7	2.4	2.2-2.6	0.73	0.53
	MS2	Rain water (A)	34	1340	6.9	5.6	1.3	0.83-1.7	1.2	1.6
		Surface water (B)	34	1340	6.6	4.8	1.9	1.7-2.2	0.78	0.62

a. Number of sample sets
b. Total spiked throughput (l)
c. Concentration (arithmetic mean) per 100 ml sample, log_{10} units
d. Concentration (arithmetic mean) per 100 ml sample, log_{10} units
e. Arithmetic mean log reduction value (LRV) = log_{10} (influent / filtrate).

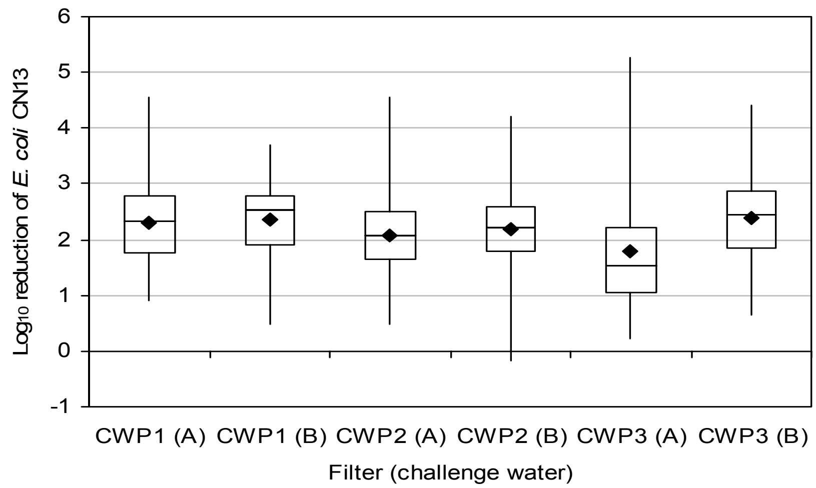

Figure 21 – Brown 88

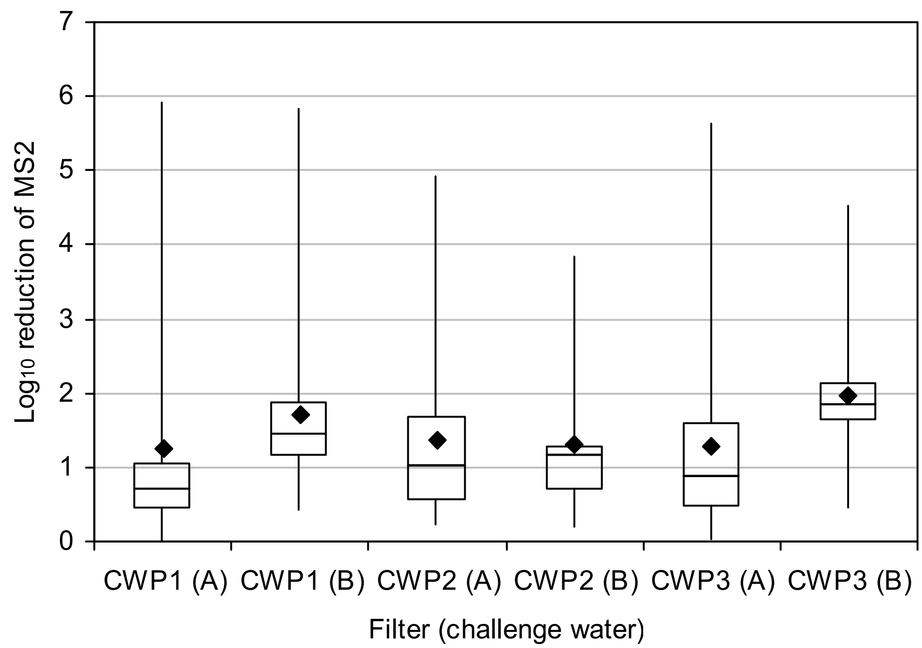

Figure 22 – Brown 89

The key findings from this study were that CWP1 and CWP2 significantly reduced surrogates for waterborne bacterial and viral pathogens, such as *E. coli* bacteria and viruses (laboratory testing only. *E. coli* was reduced greater in the CWP1 filter, followed by the CWP2 and CWP3 filters). (Brown 85)

Although it is recommended that silver be applied to ceramic filters, the results of this project did not find that the silver actually improved the effectiveness of the filters. The CWP3, having no application of silver, was observed to be comparable in microbiological effectiveness to the CWP1 and CWP2 (with silver amendments). The addition of iron oxide to the clay before firing in CWP2 did not significantly change the effectiveness of the filters against *E. coli* or MS2. (Brown 85)

Based on all these results, we conclude that, for a community like Matènwa's, the best design for a rainwater harvesting system would use PVC gutters to channel it to the an above-ground water tank. Once the water is stored in the tank, local people could use it for several household applications, such as washing, as well as for irrigating. A separate ceramic filter could be used in an extraction pipe used to collect drinking water.

The question remains as to how these technical recommendations can be made into practical reality. How can the community be encouraged to attempt to build and maintain a comprehensive rooftop rainwater collection system?

Relevance of Participatory Rural Appraisal in Matènwa

The people of Matènwa have endured atrocious living conditions while their natural resources were stripped and used to supply the mainland of Haiti. This destructive process has left the village deforested with few economic opportunities to lift itself out of poverty. The people of Matènwa have consistently shown courage in the face of overwhelming odds. They have shown resiliency by turning to untraditional means to support the community, such as through their art and culture. They welcome education as a means to a better future. The people of Matènwa are proud people who face a daily struggle to survive. They face some of the highest death rates in the Western Hemisphere; they lack sanitary water and are largely isolated from assistance that might come from the mainland and the rest of the world. Nevertheless, humanitarian aid would only temporarily stem problems that continue to grow. Reports from Matènwa, from Zanmite and others, indicate that the community is making concerted efforts to assure themselves of a brighter future. The Matènwa Community Learning Center (MCLC) and the community are building farms; they are planting trees in an attempt to reforest the area around them, which will eventually help the soil retain water; they are educating the young and old alike; they are creating beautiful art work to sell as a way to support themselves. With the community involved in these other positive initiatives, it is an opportune time for them to tackle the fundamental problem of acquiring sanitary drinking water and adequate water for their agricultural needs. Without water the trees that the community plants won't grow, the animals they try to raise will be weak and die, the farms they are building will produce very little food, and most fundamentally the people of Matènwa will continue to die from cholera and other diseases. We believe that by their creating a self-sustainable water collection system, the people of Matènwa can succeed in all their projects and their goal of a better future. This water collection system will need to be built and maintained by the people of Matènwa themselves. Zanmite and other outside agencies devoted to helping these people can help them organize themselves toward achieving these goals by application of the methods of Participatory Rural Appraisal, leading more directly to community empowerment.

Techniques such as those used in Participatory Rural Appraisal (PRA) can be used to empower the people of Matènwa to find a better solution to their water problems by engaging them in the assessment, planning, implementation, monitoring, and evaluation of the clean drinking water problem. Such engagement will lead them to ownership over the effort to create rooftop rainwater catchment systems for the entire village. Villagers in Matènwa are well aware of the problems created by the shortage of water and they are familiar with the cycle of rainy and dry seasons on their island. Having built their own homes, they have valuable knowledge about how their rooftops can be adjusted to create suitable vehicles to collect drinkable water. PRA can be a catalyst to create positive improvement in water collection and help the community of Matènwa find self- sustainability and a better standard of living. To illustrate how techniques used in PRA would be applicable to a project of building a rooftop rainwater collection system, one should note the basic principles and philosophy of this community empowerment method.

The Freirian theme at the heart of PRA states that "the poor and exploited people can and should be enabled to conduct their own analysis of their own reality."(Ideas derives from pedagogical teachings of the Brazilian educator Paul Freire, 1921-1997) This PRA philosophy accepts the idea of indigenous technical knowledge (ITK). ITK states that rural people are themselves knowledgeable on many subjects that touch their lives. Indigenous peoples have proven themselves very capable at generating and analyzing information, as well as implementing and evaluating development programs. PRA assumes that local people have the ability and capability to do anything, until proven otherwise. This philosophy becomes the driving force behind the interactions between the community of Matènwa and those who seek to help it from the outside.

The people of Matènwa should be encouraged to collect data concerning vital aspects of their water problem (i.e. use PRA methods), including such things as:

A. Rainfall Patterns
B. Needed capacity of the external tank for household or collection of households
C. Optimal placement of tanks
D. Potential environmental effects on the system, such as hurricanes and earthquakes.
E. Natural resources, such as bamboo, available to assist in the building of the systems.
F. Identification of the neediest residents
G. Construction skills available in the community

It is important to understand the rainfall patterns in Matènwa, and to do this the community should have “seasonal calendars” that the local people would use to collect the rainfall data from the community. This way they would be able to map the days of rainfall and the volume. Another useful PRA tool is the “time lines and trend and change analysis” that is used to map out potential environmental dangers to the systems, such as hurricanes and earthquakes.

The people of Matènwa are very knowledgeable about the natural resources in the village that might be used in the building of water collection systems. As in the case of “seasonal calendars,” use “transect walks” as just an example of what might be done to get the local folks engaged in the project. During walk making observations on living conditions of people in Matènwa such as sanitation, drinking water sources, volunteers, etc., is the idea of "transect walks". The empowerment of a community means that even the opinions and ideas of the neediest members of the community are taken into consideration. It is important in PRA to ensure that the poorest and least powerful are empowered in the process, and that their priorities and concerns are expressed, understood, and explored. To help identify the neediest members a ranking system that identified well-being, wealth, and livelihood can be used. Also a transect walk could be helpful in identifying if certain areas of the village are worse off than other areas.

The placement of the tanks is a crucial aspect of the project in which all community members need to be involved. A better community understanding of the placement could be achieved by a "presentation and analysis" technique that asks the community to create maps and diagrams of the village, and then these visual representations can be discussed to establish where the best locations for the tanks are.

The final piece of information that needs to be taken into consideration is the availability of the community to participate in the construction process. The community would have to analyze daily data and participate in planning, budgeting, implementation and monitoring. The community will be able to create diagrams and time lines to display the amount of time different activities will take, and will establish the difficulty of each. The community thus organizes itself by finding an efficient and equitable way to distribute necessary tasks.

The methods of PRA can be used to empower community members to take ownership of this project and to allow them to create innovative ways to solve their water shortage problems. PRA could serve as the catalysis of the project to build rooftop rainwater harvesting systems. The process of encouraging the self-organization of a community can have lasting effects when the community faces new challenges in the future.

To ensure that the needs of Matènwa's people are met, it is essential that all aspects of the water crisis be examined and that all related factors are considered. In order to make water available to each household, and to make the task of obtaining water less strenuous for the people, the idea of installing water storage units for each house (or group of houses) was explored by this project. The advantages and disadvantages of water tanks and water cisterns were studied and cost effective materials were researched for each, reaching the conclusion that by reducing some costs of underground cisterns, they were preferable to more easily damaged above ground tanks. In addition to obtaining water, its sanitation is equally important. To address this issue the use of ceramic filters was investigated and a case study done by a PhD Graduate student of the University of North Carolina at Chapel Hill was used to compare the effectiveness as well as the affordability of different ceramic filters. The most important element of any solution is the people it is designed for. Participatory Rural Appraisal illustrates techniques that will mobilize the people of Matènwa to work together to successfully implement a rooftop rainwater harvesting system. By understanding a community's culture and habits, those who seek to aid in the development of other peoples can devise self-empowering solutions—solutions that involve all members of the community, giving them ownership for the success of a project and ensuring that the community will work as a whole to achieve success. This type of collective success is what we would wish for the village of Matènwa

Conclusion

After considering the main options of rainwater catchment (single roof water collection, large roof water collection systems, land surface catchments and storm water catchments), the most suitable catchment system for Matènwa is the single roof water collection system. Unlike the large roof water collection, which needs a lot of materials for piping and construction, a single roof water collection system largely reduces the complexity of construction and its cost while being equally effective.

Similarly, catching the runoff water on the ground using land surface catchment would not be a suitable option for the community of Matènwa because of the soil's inability to retain water as well as the uneven structure of the mountainous village. On the other hand, using single roof water collection systems on the houses of Matènwa still proves to be the a better option considering the time, effort and money that would be required in the building and maintenance of the systems.

This system would be implemented by installing gutters on the rooftops of the houses in order to be able to capture the rainwater and send it, through the gutters, into the storage system. For the storage system we considered two different options (water tanks and cisterns), both of them have their advantages and disadvantages. However, based upon our research, the use of under-ground water cisterns is a more reasonable alternative than above ground tanks because of the conveniences brought to the users. The key advantages of the water cisterns are the little amount of materials needed and the low construction cost. Both options are exposed to natural hazards, but water tanks are more easily damaged due to external exposure.

Once the water is stored it can be used for many different purposes, such as cleaning, showering and watering plants. However, for drinking water, since the caught rainwater has to travel through the gutters and these may not be completely clean, the quality of the water may be affected. Therefore, because only a small fraction of the collected water would be used for drinking, we have proposed to have a filtration system, which will be separated from the storage system.

This filtration system will consist of a low cost filter bucket model, composed of two plastic buckets stacked on top of one another the size can vary with the size of the family). In the top bucket, the ceramic filter will be placed in a pot shape, while the bottom bucket can collect the purified water, as it is shown in Figure 23.

Figure 23– Examples of Low Cost Water Filter Buckets

Whether or not it is written in a country's constitution, there are certain inalienable rights that all humans are entitled to. The right to clean drinking most certainly falls under that category. Our research on Haiti makes it very clear that for the people of Matènwa, as in many other rural villages, life is an everyday struggle. The average Haitian lives off less than two dollars per day, and about 47% of the population are illiterate. The government that is responsible for protecting its people has often been corrupt and ineffective. It is unfortunate that even the very land that the people live on is now of power quality because of the severe deforestation. The devastating earthquake that occurred in 2010 has added considerably to the problems of the nation. Despite all of this, the people of Matènwa possess an unwavering will and remarkable sense of unity. It is these qualities that have enabled the people to persevere, and that will help them achieve success in resolving their water problems. With the help of organizations such as Zanmite, Haiti Outreach, the Matènwa Community Learning Center and others, the people have received training in work skills, valuable education, and some water wells have been dug. Even with all these efforts being accomplished there is still a lot of work to be done. Our proposal for using rooftop rainwater collection and then water storage in cisterns requires a commitment from the people of Matènwa as well as the outside aid organizations. As is common in Haitian villages, the people of Matènwa help each other, knowing that one of the few things they can rely on is one another. To ensure the success of any development project, the people of Matènwa must play an intricate part of the solution. They must be involved in rooftop rainwater harvesting project, to ensure that it will be maintained in the future. By encouraging the community to act collectively for this project, Matènwa will be greatly empowered to address other fundamental problems hindering the development of the nation. By utilizing the efforts of each community—and every member of each community, rich and poor alike—Haiti will increasingly become the democracy envisioned by Toussaint L'Ouveture when he proclaimed the First Free Black Republic.

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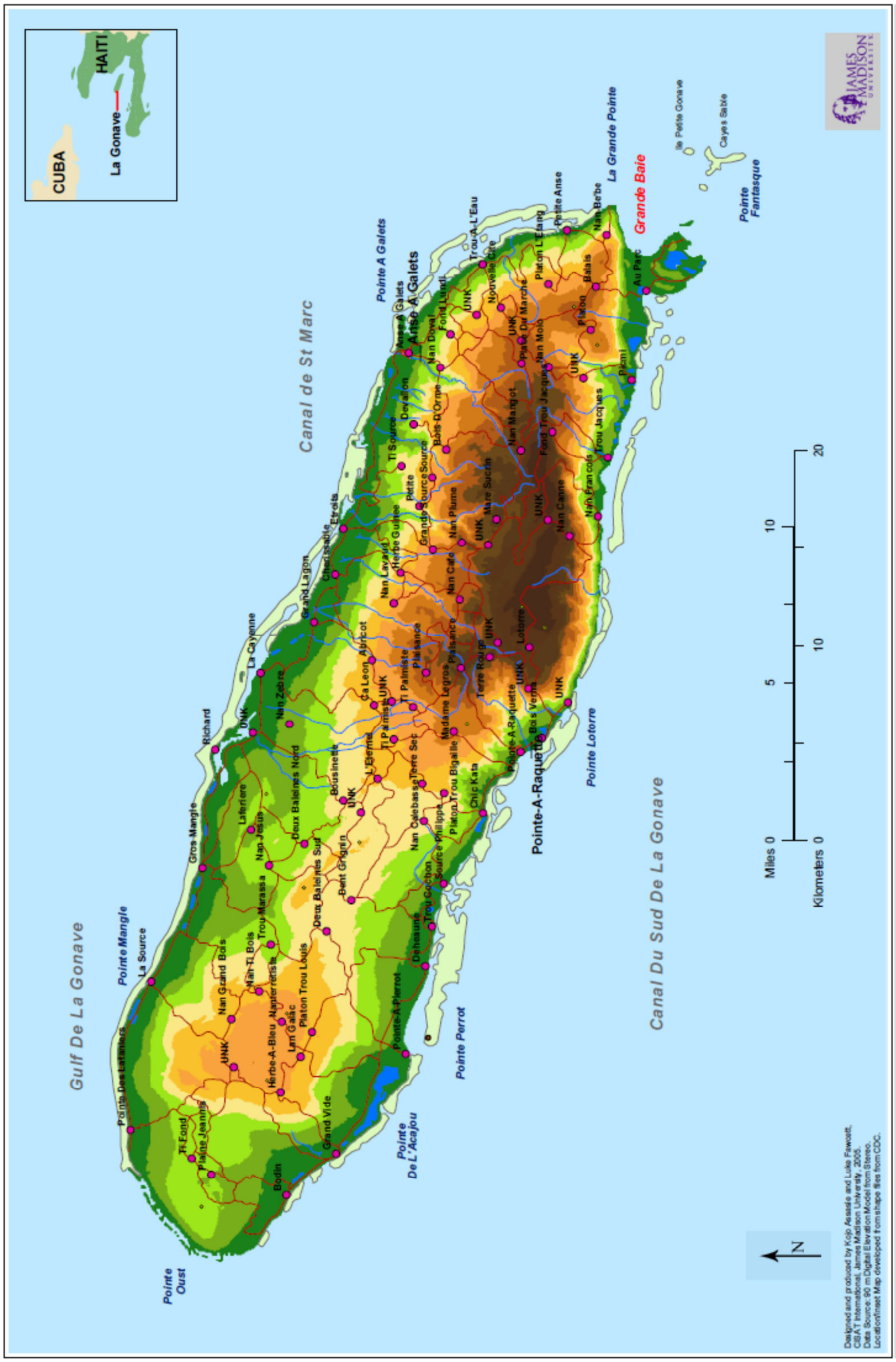
Appendix A

Map of La Gonâve, Haiti



Appendix B

Calculations for rainwater catchment

With all the data about annual rainfall, runoff losses, and typical square footage for the houses in Matènwa, the number of gallons that could be collected in a year were derived using the following equations:

$$Volume = Area * height$$

$$1\ cubic\ foot = 7.48\ gallons$$

Having the following data:

$$Annual\ rainfall = 47.24\ in. = 3.94\ ft$$

$$Larger\ Area = 288\ sq\ ft$$

$$Smaller\ Area = 160\ sq\ ft$$

$$Runoff\ Coeff. = 0.85$$

Yielding the following results in cubic feet:

$$Volume_{288} = 288\ sq\ ft * 3.94\ ft = \mathbf{1134.72\ cu\ ft}$$

$$Volume_{160} = 160\ sq\ ft * 3.94\ ft = \mathbf{630.40\ cu\ ft}$$

Or the following in gallons per months:

$$Volume_{288} = \frac{\left(1134.72\ cu\ ft * 7.48 \frac{gallons}{cu\ ft}\right)}{12\ months} = \mathbf{707.31\ gallons/month}$$

$$Volume_{160} = \frac{\left(630.40\ cu\ ft * 7.48 \frac{gallons}{cu\ ft}\right)}{12\ months} = \mathbf{392.95\ gallons/month}$$

And after applying the runoff losses, the results are the following:

$$Volume_{288} = 707.31 * 0.85 = \mathbf{601.21\ gallons/month}$$

$$Volume_{160} = 392.95 * 0.85 = \mathbf{334.01\ gallons/month}$$

Appendix C

Detailed calculation of the amount of water needed at healthy living standards.

As shown by the World Health Organization, 20 liters of water every day is considered as a healthy drinking living standard. Therefore, for a family size of 4 individuals, the water needed per house is the following:

$$1\ liter = 0.264\ US\ Gallons$$

$$20\ liters * 4\ individuals * 0.264\ gallons/liters = 21.12\ gallons/day$$

$$21.12\ gallons/day\ * 30\ days/month = 633.60\ gallons/month$$

And, for a family size of 6 individuals, the water needed will be as follows:

$$20\ liters * 6\ individuals * 0.264\ gallons/liters = 31.68\ gallons/day$$

$$31.68\ gallons/day * 30\ days/month = 950.40\ gallons/month$$