Green Building in Haiti
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Executive Summary

The rural village of Cange has a desperate need for housing development for displaced Port au Prince residents and the families of new patients at the local Zanmi Lasante hospital. This housing must take Haiti's moist, hot climate into account, must not require wooden framing, and must be a simple enough process for inexperienced people to learn to build. Ideally, housing will also be culturally acceptable to residents and include technologies low-energy technologies that will improve their quality of life. We outline how this may be accomplished using earthbag construction methods and eco-technology concepts like passive solar design, water treatment and retention, and natural ventilation design.

Purpose Statement

The village of Cange, Haiti currently houses between 8-10,000 residents and is expected to grow rapidly in the near future partially due to the presence of the Zanmi Lasante hospital but also more recently due to internally displaced persons from the earthquake disaster near the capital city, Port-au-Prince. Cange needs sustainable building design to accommodate this growth. The goal of the project is to provide current and incoming residents with an actual home design to be constructed using predominantly locally available materials at a low cost to the owners and surrounding environment. Several do-it-yourself eco-technologies will also be presented.

Overview of Client

The January 26th earthquake with an epicenter in Port-au-Prince, Haiti resulted in the need for many people to move to refugee homes in the village of Cange. Before the earthquake, an estimated 704,776 people lived in Port-au-Prince, 2 million in the metro area and 8-10,000 in the city of Cange. Because Port-au-Prince was one of the largest centers for economy, finance, and education for the country, it is a great challenge to provide support and maintain the culture of the displaced people. The current population of Cange is largely made up of people displaced from lowland communities following the flooding of the surrounding area after the construction of the dam on the Artibonite River in 1956. The rural city of Cange is expected to have its population double in the next year as earthquake displaced persons relocate out of the city.

Pre-earthquake Port-au-Prince was a strong educational and vocational center for the country, with multistory buildings equipped with modern running water and electricity features not found in much of rural Haiti. The city's commerce is based around the production of baseballs and shoes, as well as exporting dry goods like coffee and sugar. The village of Cange is much smaller; a rural outpost with single room homes and very little in the way of exporting and trading. There is no electricity in most homes, and the water comes from one of six fountains in the village. This

Figure 1. Devastated local housing in Jacmel, Haiti. Wikipedia, Earthquake, 2010
water is supplied from a capped mountain spring that is pumped up the mountainside through an underground cistern. Toilets are also either not used or are compostable and kept in locked private privies. The majority of waste is improperly disposed of, creating the risk for groundwater contamination through the porous limestone rock formations that make up the ridgeline where Cange is perched. The two cultures are very different and accounting for differences in ways of life for relocating families will be necessary for a smoother transition of urban families to rural accommodations.

The city of Cange is located at 18° 55’ 0N latitude and 71°58’60W longitude at an elevation of 656 feet. The community sits on the Central Plateau, eighty miles from Port-au-Prince. There is a lake near the village from the damming off of the local river. The city “is located among the steep terrain, which leads to the rugged uplands of the interior plateau.”[S.Lansing]. Deforestation of nutrient-poor tropical soils has caused soil erosion in the area, which is now made up of limestone with layers of sandstone and clay. The climate is semi-arid with high humidity near the shoreline. Two rainy seasons occur between April and June and October through November. Deforestation has caused more severe damage in the wake of droughts, floods and hurricanes.

The area needs a strong community development plan. With a drastic increase in population, organization is key to keeping order, providing municipal and day-to-day services and helping to restructure the culture from which the refugees came from. As part of that effort, designing buildings that are low cost, bring in an ecologically friendly design, are adaptable to extreme weather conditions and help maintain the lifestyle of the refugees (or at least incorporate that option) is very important. This includes running and clean water, options for the disposal and transport of waste as well as a commerce center for goods trading, education and community gathering. If possible, adapting modern technology for cooking and other non-rural adaptations for the new Cange citizens could help to ease their transition. The most pressing needs are for safe, weatherproof, and basic shelter with modern considerations to help incorporate the individuals into the town.

**Eco-Technologies**

**Earthbag Construction**

**History of Earthbag Construction**

Earthbag construction is one of several related earth-building techniques, a genre that includes rammed-earth, adobe, and cob. Earthbags differ from these other methods in that there are no forms or specific soil types needed to create each layer of the wall. Rather than relying on structural aspects of soil types like clays or sand, earthbags are simply polypropylene or burlap sacks, filled with locally available site soil and layered like giant bricks to form a thick, sturdy wall. While most evidence for the historical use of earthbag-style building is anecdotal at best, the general technique has been used by militaries in the form of sandbag reinforcement walls and bunkers since as early as WWI. In the late 1970s, architect Gernot Minke experimented with single-storied earthbag structures, using cotton hoses filled with ground pumice (Kennedy & Wojciechowska, 2005).
In the 1990s, the earthbag technique was picked up by a Persian architect working with the California Institute of Earth Art and Architecture (Cal Earth), Nader Khalili (Kennedy, 2002). Khalili patented a variant of earthbag building in 1999, trademarked “superadobe” (U.S. Patent #5,934,027, #3, 195, 445) using specially sewn long bags to create domed beehive-like structures. The system is “freely put at the service of humanity and the environment. Licensing is required for commercial use.”, in a post-patent statement by Khalili, though it has been argued that the patent should never have been issued, since the process was highly publicized for a full year before the patent was applied for. Khalili and his followers have been the main drivers behind most recent construction projects and research into the various uses of the technology, leading classes in the super-adobe construction method in the American Southwest. They strongly support its use as disaster relief housing, touting its durability, ease of construction, and low material costs.

Earthbag construction methods have many features that make them particularly well suited for providing housing in disaster-stricken areas. The most evident...
of these features is their very low cost. Using earthbags, a rubble trench, earth plaster, and locally harvested/recycled wood for interior features, these buildings could be constructed in the US for about $10/ft² (Geiger, 2010). This number does not include land or labor costs, but they are generally constructed as community projects with free (volunteer) labor. For an example cost

<table>
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<tr>
<td>Load of Dirt</td>
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<td><strong>Total</strong></td>
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<td><strong>$2,168.95</strong></td>
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Figure 4. Example cost sheet for project in Port-au-Prince.

sheet of a project recently completed in Port-au-Prince, see Figure 4. According to earth bag building expert Kelly Hart, *The China Forest Packaging Group* in Qingdao, China “can provide a wide range of polypropylene bags, both as individually sewn bags, and as long tubes on rolls. They ship via containers and can send these all over the world…including Haiti. Standard 18” X 30” bags run about $0.11US each and the longer 18” X 34” bags are about $0.12 each. The same bags with UV stabilization are about a penny more. These prices are FOB Qingdao. The cost of shipping a 40’ container to the East coast of the US runs about $3,200US and this can hold about 330,000 bags….so this would add about a penny per bag.”

Bags can also be obtained for free in some situations, as they are the same bags used to ship dry good like grains and rice all around the world. Earthbag constructions also eliminate the need for wood framing of walls, provide high external thermal mass to mediate temperature flux, and with experience, may be built as round, domed structures with documented earthquake stability.

**Constructing Earthbag Homes**

While rounded buildings require more practice and help with earthquake stability, inexperienced builders can easily master the building technique for simpler, straight walled structures. This is
ideal for disaster-stricken communities where homeowners must become homebuilders. The actual process of building with earthbags is quite simple. The site is prepared, clearing any organic material and topsoil aside for other uses and digging a basic rubble trench. Concrete foundations are an unnecessary expense, due to the width of the walls themselves. Fill material, usually site subsoil, is then prepared by moistening and leaving them overnight. This ensures that the soil will be easy to compact thoroughly with a heavy tamper. Bags are then filled halfway, moved into position, then filled completely using a wheelbarrow—full bags are heavy and awkward to move. For higher wall sections, it is generally recommended to move smaller volumes of soil up to the bag using buckets, to reduce heavy lifting. Bag rows are constructed by pinning the first bag securely, followed by subsequent bags which are folded closed, then laid with their folded end butted up to the sewn bottom of the preceding bag. For rounded walls, each layer (course) is corbelled slightly inward. Once a full row is laid, alignment is adjusted and bags are pressed into an approximation of final placement by standing on the bags. When the row is plumb, a tamper is used to gradually compact the bags into a relatively uniform level. When the tamper makes a “ringing” tone and the bag has no more give, it is sufficiently compacted. Each subsequent row of bags is laid so that the joints of the lower row are covered, like laying bricks. A layer of barbed wire can also be added between rows to keep bags from slipping in earthquake prone areas, acting much like the steel rebar used in concrete construction. Layering is repeated until the walls have reached the desired height, and the top perimeter is stabilized with a poured concrete bond beam. Roof construction is the same as in traditional construction methods (unless the structure is domed). Once the roof is in place with at least 36” of overhang, walls are plastered with either earth plaster, lime-earth plaster, or sprayed concrete, which can be under laid with plastic or wire mesh for added stability. This ease of construction lends itself to community build projects readily—with experienced help on the first building, residents can easily gain enough experience to teach a new group of builders in later projects.

Earthbag construction methods are often touted for their earthquake stability. According to one prominent earthbag home designer, “Earthbag buildings tend to flex and distort during an earthquake rather than suddenly collapse as wood framed, adobe, brick and concrete block structures do. Barbed wire and plaster mesh hold the bags together in case of collapse, thus greatly reducing risk of people getting crushed.” When building in earthquake-prone areas it is recommended that earthbag homes are built in curved or rounded shapes when culturally appropriate. In the 1990s, Nader Kahili and the Cal-Earth crew had structural tests performed on their dome structures in Hesperia California, addressing live-load and dead-load, static, and dynamic loading forces. The results were recorded as successful by the ICBO-approved testing lab Southwest Inspection and Testing. Following six years of engineering review and testing, California building permits were issued for the use of superadobe structures as housing (Cal-Earth, 2010). Un-reinforced earthen structures had been forbidden in California for the last 50
years whereas the stabilizing measures taken in earthbag building have made it acceptable in a state with some of the strictest seismic code requirements in the US. These testing results cannot be assumed for other earthbag designs, but they are encouraging for the future of sustainable building in earthquake-prone areas. Other ways to improve the earthquake stability of an earthbag home include avoiding long unsupported walls, using strands of 4-point barbed wire between courses and plaster mesh, limiting the number and size of doors and windows, building with lightweight roofing materials, and using traditional strengthening techniques like concrete bond-beams with truss anchors (Geiger, 2010). With a combination of these efforts, the structure should hold together even if walls topple, reducing the crushing risk posed by any structure that receives a direct hit from a major earthquake.

The majority of research in and applications of earthbag construction methods has been in the American southwest. The warm, arid climate of this area lends itself well to earthbuilding methods, eliminating the need to be particularly concerned with waterproofing, insulation, or rainwater catchment complications. However, this by no means implies that earthbag methods cannot be used in colder or wetter climates- according to Kelly Hart, an expert in earthbag buildings; they have been constructed in areas such as Thailand, Hawaii, Mongolia, Belize, Honduras, Haiti, and the Philippines (Hart, 2010). To adjust for wetter climates, it is recommended that one uses vertical walls and a long eaved roof in the place of the popular domed roof style, which bears the full brunt of storms on its wall surface and can be difficult to gutter. For colder climates, earthbags can be adjusted to serve as insulation rather than thermal mass by simply filling them with materials like volcanic pumice, scoria, vermiculite, or perlite (Geiger, 2010). Perlite has an R-value of 2.7 per inch- in a standard 15inch wall, the building would be insulated with an R-value of 40, which meets recommended insulation values for the coldest parts of Canada (Polyiso, 2010).

In wet-climate applications, earthbag structures have some features that will require particular attention paid to waterproofing efforts. Drainage plans should be made from the start, with well-dug rubble trenches and tile drains where needed, to direct water away from the structure. Walls should be plastered with concrete or a lime-clay mixture, and roofs should be built with large overhangs to minimize the direct wetting of the walls during rainstorms. The bottom few courses of bags can be filled with gravel rather than soil if wetting is a serious concern. These measures will also mitigate the potential for UV degradation of the polypropylene bags, blocking direct exposure of the plastic to sunlight and extending the life of the structure. Other concerns have been raised about the potential for soil walls to harbor ants and other ground-dwelling pests, a potential annoyance or even hazard in areas home to fire ants or scorpions. Experts recommend thorough soil compaction during the construction process and plastering to reduce the wall's habitability for soil pests. The tight weave of polypropylene bags (as opposed to burlap, which can also be used to contain the building soil) can also act as a pest barrier. With polypropylene bags, proper plastering, and a well-dug rubble trench, most problems inherent to earthbag construction can be properly managed.
Passive Solar Design

Air conditioning is not the only way to accomplish a comfortable living environment in a tropical location. There are a number of ways to intelligently design a home and its surrounding landscape to minimize heat gain and maximize comfort naturally. The two dominant design aspects easily attainable by the residents of Cange are the smart use of shade and airflow.

**Roof overhang**

Roof overhang in the tropics is very important for both sun and rain protection. The overhang length for the south-facing wall was calculated using the Solar Radiation Data Manual for Buildings published by the National Renewable Energy Laboratory (NREL 1995). There were no data for Haiti although we were able to use data from San Juan, Puerto Rico because the geometry is almost entirely based on latitude and San Juan is only one-half degree south. The overhang length provided by the NREL guide is designed such that the south-facing windows are completely shaded at solar noon year-round. This is because the region has no heating degree-days and cooling is the only issue of concern.

**Figure 6.** Sketch showing ideal use of trees for passive summer cooling design.  
<http://www.thedailygreen.com/cm/thedailygreen/images/pO/summer-shade-trees-lg.jpg>

**Shade trees**

Shading the home and minimizing any heating of its surfaces above the ambient air temperature is essential in the passive cooling design (Figure 6). It is especially important to keep the earthbag walls shaded because they have such a large thermal capacity. In the tropics, with very little diurnal temperature fluctuations, there is no chance for the walls to cool themselves at night as is the case with most earthen wall construction in the arid American Southwest. Our goal with the earthbag walls is to keep them shaded and connected to the earth where we hope they will conduct away any heat they gain through the day. Shading the home will help immensely in accomplishing this. Haiti currently has about 2% forest cover (Lib. of Congress 2006). Massive deforestation in the last hundred years is due to use of wood as a fuel source and lack of
governmental regulation and oversight. Growing trees next to houses to shade them and provide some other type of benefit makes sense. The Organization for the Rehabilitation of the Environment is currently promoting use of new varieties off-season and drought tolerant tree crops. Mangoes are among the largest of Haiti’s exports and comprise 13% of the US consumption (University…2010). Much of the work revolves around Mangoes but they also promote propagation of avocados, citrus and bamboo.

Constructing with bamboo
Bamboo is a fast-growing woody grass that has been used for hundreds of years by humans for constructing structures, among other things. There are over 1000 species that are found all around the world though they occur mostly in the tropics (Farrelly 1984).

Some locally grown bamboo species are currently used in certain regions of Haiti to construct homes but their durability is limited by rapid infestation by mites. Efforts to introduce more hardy varieties are currently being pursued by the Organization for the Rehabilitation of the Environment (ORE). The group has a large nursery in Haiti in which they are propagating and promoting the use of these hardier varieties for erosion control and as a local sustainable lumber source.

There are several ways to treat the bamboo to extend the life of the wood. First, fresh cuttings can be submerged in a fresh flowing river for 4-12 weeks to in order to leach out the starch and sugars. The wood is a much less desirable food source for pests once these compounds have been extracted. The second practical way in which local Haitians could treat their own bamboo would be to smoke or heat it. Smoking the wood in its own resin also makes it unpalatable to insects. However, it can be difficult to find or construct a container large enough to hold the lumber whole. If it can be found, one can also coat the lumber with borax. Any of these treatment methods should increase the lifetime of the wood significantly—to 30 years in some cases (Rottke 2003). Regardless of which treatment is used, the wood needs to be ambient air dried in covered storage for 6-12 weeks. They should be stored flat and level so they cure straight.

Water and Irrigation Systems
In order to account for the increase of storm water runoff by reduced infiltration areas, we designed a set of required and optional irrigation techniques depending on the cost, availability, taste, and willingness to perform upkeep tasks from the new residents. These include rain barrels, slow sand water filtration

![Figure 7. Bio-sand Filter as designed by Dr. David Manz at the University of Calgary, Canada.](image-url)
systems, raised bed gardens, and increasing local root systems (such as by planting trees). These systems not only help to make the lifestyles easier by reducing wait times at public fountains, but also reduce the risk of possible contamination and harm due to increased nutrient runoff from ‘naturally displaced waste’, water pooling and land slides. When put together, these systems will help the Cange citizens live healthier lifestyles and have more free time to put towards other daily tasks and activities.

**Slow Sand Water Filter**

In order to account for the increase of storm water runoff by reduced infiltration areas, we designed a set of required and optional irrigation techniques depending on the cost, availability, taste, and willingness to perform upkeep tasks from the new residents. These include rain barrels, slow sand water filtration systems, raised bed gardens, and increasing local root systems (such as by planting trees). These systems not only help to make the lifestyles easier by reducing wait times at public fountains, but also reduce the risk of possible contamination and harm due to increased nutrient runoff from ‘naturally displaced waste’, water pooling and land slides. When put together, these systems will help the Cange citizens live healthier lifestyles and have more free time to put towards other daily tasks and activities.

The use of the filters has been reported as easy to use by both children and adults, requiring no more than removing the lid and pouring in water. Water can enter the filter from a rain barrel or directly from rain water. A diffusion plate will catch large debris, which can be simply removed by hand. The plate also diffuses the turbidity of the water as it passes through to the schmutzdecke, a biological film that traps and feeds on microorganisms and contaminants in the water. To work properly, the schmutzdecke must always be wet and remain undisturbed by the water pouring process- through the system's design, both of these conditions are usually met. Water then filters down through a layer of sand and gravel and out the pour spout at the base of the unit. The pipe connected to the spout runs from the bottom of the filtration system (where the gravel is) to the level of or just above the schmutzdecke layer, so that this layer stays wet at all times. Odors, strange tastes and turbidity are removed in the layers of sand and gravel.
These sand filters can be made by hand using trash barrels, a filtration bucket (5 gallon buckets are most often used), PVC, sand and gravel. The barrel holding the sand and gravel should be assembled where it is intended to be used, as once full, it is very heavy. The size will not matter, but thickness proportions of sand, gravel and area for the schmutzdecke to develop should remain the same. The diffuser for water going into the schmutzdecke has been built by puncturing holes in the bottom a five gallon bucket (mounted on top of the filter barrel) or using a punctured PVC pipe system incorporated to the outflow of a five gallon bucket for slow drip designs. Suggested sand and gravel ratios can also be found below, but designs have been recommended in 1:1 ratios for the different sand types. If only one type is available, that will work as well. Please note that the drain pipe assembly can either have a similar design to the
inflow piping shown below or can just be a pipe flowing from a punctured hole on the side of the bucket and the air vent is only required if the infiltration system fits the opening of the bucket. This design is not recommended as it is more likely to get gravel in the flow system thereby creating stress on the join and reducing the lifetime of the system. The outflow piping must be the same height as the schmutzdecke level. A Youtube video demonstrating how to build a biosand filter (in French) is also available, showing how they can be made by local citizens (MainAmpy 2008). The first barrel has a flow rate of 12.7 L/hr.

Rain Barrels

In conjunction with the sand filtration system, water barrels provide an easy solution for collecting and storing water for later use. This water can be used as wash water, irrigation, or drinking water after further treatment. Rain barrels collect water from the roof of new homes and reduce the amount of storm water runoff from the site as impervious roof surfaces are placed. These rain barrels will be designed with lids, but can be modified if no lids are available. The downspout from the gutter will run directly into the top of the barrel with a tight connection between the spout and the lid to reduce the number of contaminants, rodents, and bugs that can enter the barrel. This reduces maintenance and increases the length of time water can be safely stored. A picture of the combination rain barrel and water filtration system can be seen above. Our suggestion is that a 55 gallon barrel be used, which can sometimes look like the pictured barrel, or can look like a plastic trash can with a lid. Screens can also be fitted at the inflow point so that any water coming in is filtered from larger animals or debris, reducing the chances for contamination. Water is discharged from the base of the barrel as needed.

Raised Garden Boxes

On occasions like particularly large storm events, the rain barrels will overflow with rain water from the roof. Houses without rainwater catchment systems will face the risk of water reaching the walls of the house in most rain events. Raised garden beds fed by an overflow valve near the top of a rain barrel or fed by the gutter of a home without catchment structures can serve this purpose, using water directly for irrigation and slowing its rate of flow to reduce erosion. Having an overflow system or protective barrier will help to reduce damage to the home, create an opportunity for local citizens to raise fruit or vegetables, reduce costs to the family and increase community health. This would be an optional addition to a basic house design, and would incorporate seasonal variations, plant availability, and community need. For more information, see the Ecological Design Project for Agroecology and Community Agriculture project.
Composting toilets

Several organizations providing aide to Haitians have found that citizens do not know how to use compostable toilets and need to be created in a separate structure from our housing design. It is worth mentioning for health and sanitation considerations especially in mass house settings. Training and education would need to be implemented for the local citizen to indicate which portion is used for urine and where feces are to be dispensed. A low cost design can be implemented to begin, with either two buckets (one for urine and one for feces) or one bucket with a tube that diverts urine given a two part design (see seat to the right). This system reduces water and can create a community resource for crop production or to fertilize local plants. It is also a potential contamination source and needs a proper disposal plan (such as an designated spot for composting).

A more expensive and luxury choice composting system incorporates end use aerobic decomposition through three different sources. This includes an pre-heated air stream system that passes through and over a solar collector system and under a set of stairs supporting the outflow piping, the air that enters through the PVC piping and the air over the pile, removing carbon dioxide. As the sun heats the back of the solar chimney, the air is heated, circulates naturally, pulling air through the composting system. The separation of urine and feces reduces opportunities for a foul smell.

A rich carbon source such as grass clippings, sawdust, leaves, peat, and/or wood chips should be added after each ‘flush’. “The humus that results is only five to ten percent of the original volume as ninety to ninety-five percent will be transformed into carbon dioxide and water vapor and released through the vent. It will take approximately two years for the first decomposition period, then with the continuous process, three to ten gallons of humus will be produced per person per year.” [Longbranch EEC, 2005].

**Passive Solar Composting Toilet**

![Diagram of a passive solar composting toilet](image)

**Figure 14.** Composting toilet from LBEEC.
Design for Cooking

Traditionally, Haitians cook outside their homes. We have kept that consistent in our building design with space for an outdoor kitchen on the south porch. If they were to cook inside our house however, ventilation should be adequate enough to keep air quality reasonable.

Design Description

Given this knowledge about the moist climate, lack of wood resources, earthquake tendencies of the island, and lifestyle of the residents, we have developed plans for a 300ft² basic home incorporating simple, low-emergy elements to improve living conditions such as natural lighting, passive cooling, and a water filtration system for the house. This design is intended to serve as a jumping-off point for local adaptations of the techniques and technologies to best suit personal tastes and fluctuating material availabilities.

The basic home is constructed from standard 18X30 polypropylene bags, filled with finely crushed rubble or site soil excavated during grading. When completed, walls are 15” thick, with an indoor living area of 300ft² and an outdoor living area of 162ft² under the large southern overhanging roof. The living area is split by a thin interior wall which does not reach all the way to the roof pitch, to provide a private sleeping space without blocking airflow (as a full height interior wall would) or taking up significant indoor space (as an earthbag wall would).

Doors are located on the east and south walls of the home, to provide a formal entrance as well as access to the outdoor living space from the kitchen area of the home. Traditionally, cooking is done outside the home so easy access to outdoor space was prioritized.

Windows are located under large roof overhangs (6ft on south wall, 4ft on north wall, 2.5ft on east and west walls) and may be supplemented with bars or locking shutters for safety.

The roof design, to keep construction and water collection simple, is a single slope shed roof (Figure 16). This design limits the number of seams in the corrugated tin roofing that may have eventually lead to leaking and also eliminates the need for complicated venting in the ridge. Theoretically, there are no places for pockets of

Figure 15. Building cross-section from east showing roof ventilation. Midday sun warms the corrugated tin roof driving convective air currents north along roof slope.
hot air to accumulate and heat up the rest of the house.

On a bright sunny day, the surface of the roof will get very hot and transfer much of that heat to the film of air immediately underneath it on the inside of the building. As this occurs, the air becomes less dense at its higher temperature and rises. Due to the sloped roof, the only place for the hot rising air to go is along the ceiling and eventually out the north wall vents (Fig. 5). To replace that lost air volume, cooler ambient air is pulled in from the south wall vents. This passive cooling process will also draw air out of the building interior living space including any smoke that residents may generate for cooking.

To construct the vents, rafters are laid across the tops of the walls in the north-south direction with around a 1.5-foot spacing. The vent height will depend on what type of material the builder is using. Milled soft wood 2x6s will provide approximately a 4-inch gap while bamboo poles will probably be less depending on their diameter. To help keep out pests, suspend screen material or at least chicken wire in between the rafters before attaching the corrugated tin roof. This will allow airflow but will keep anything larger than the screen spacing out. It is our hope that this design will maximize airflow as simply and inexpensively as possible.

To help shade the building, we recommend planting one of these trees on the east and one on the west side of the house. Priority is placed on these wall orientations and not the south because our house design has a completely shaded porch, though a tree to the south would not hurt. The east and west faces of the building are difficult to shade with a roof overhang due to the low angles the sun reaches. A shade tree should be planted about 10 feet away from each wall. This should provide adequate shade depending on the type and age of tree. The secondary benefit of these shade trees is that they provide food. Mangos and citrus are a wonderful source of vitamins and most likely already make up some portion of the Haitian diet, avocados are a very good source of healthy fats, and bamboo would provide a fast-growing “sustainable” source of local wood, either for use as a fuel or building material. Rain from the roof that is stored in the rain barrels can be used to irrigate during dry times.

**Haiti Connection**

When designing our green building we had to take into many different geographic considerations. Our primary consideration was designing something that could be easily constructed on site and would be able to be installed in a variety of locations. Given that the village of Cange and its surrounding area is in a very mountainous region, we were left with the obligation to design something that could be implemented not only on flat parcels of land, but also on a hillside. Our earthbag design is a perfect solution for this as it allows ease of construction on flat topography as well as sloped regions.

The second main consideration is the potential of earthquakes in the area. Our design also tackles this issue because the earthbags allow for elasticity and movement while still maintaining the integrity of the structure. By constructing for this possibility we are able to reduce the potential for reconstruction when earthquakes do strike and also our choice of materials allow us to reuse materials in the event of structural failure. The climate of the area is the third
consideration that determined our design. Haiti has a wet and dry season. While temperatures do not vary too drastically throughout the year, sunlight has a big influence on temperature during the dry season. To compensate for this we designed a single pitched roof elevated on rafters. This will allow for convective cooling caused by direct sunlight on the roof as described in the previous section. The single pitched roof also works with the heavy rain season because it is corrugated and sloped to collect water in rain barrels that can then be used by the inhabitants. Treatment of this water would increase the potential household uses to include cooking, drinking, and as irrigation. This is made possible by the available water treatment options that can be installed in each house.

In addition to the geography of the village of Cange, our design had to take into consideration the social and economic status of the inhabitants. Our design works well to accommodate the economic status of many of the people requiring this housing as its simplicity makes it very inexpensive to construct and maintain. In addition to the relatively low cost, the construction is simple enough that it can be easily taught to the local people thereby allowing a wide range of input for the manual labor. In regards to the social structure of the village our design takes this into consideration by providing ample outdoor space. We know that much of the cooking and socializing between neighbors takes place on a porch-like area outside the house. We incorporated this cultural need by designing the roof to overhang far past the walls on the south side of the house thereby creating a covered porch area. This results in an area that is protected from direct sunlight and rain while still considering the social need.

While we designed a single family home, we researched group housing. In Haitian culture, families often live close to one another, with a new couple getting a new house upon their marriage. They are very private and sometimes choose the orientation of the house based on the cardinal directions or the location of the sun relative to the house. Groups of people in the same ‘profession’ or who take on the same work will also live near one another. In designing groups of

Figure 16. Designs for group houses and cluster homes for new construction in Haiti (Stouter 2010).
housing, a group of people from Patti Stouter’s working group at Earthbagstructures.com has suggested that in building group or cluster homes, these preferences be taken into account as well as the allowance for multiple rooms or the addition thereof (see Figure 12). These will influence the location of windows, doors, rainwater drainage, ventilation, privacy and the location of shared structures (latrine, cooking area, etc.). To build stronger relationships and increase safety, they also suggested that openings face one another and that courtyard and an outdoor shared space are provided. Temporary housing using tarps between the housing can be incorporated between buildings in these designs as well to significantly increase short-term housing capacity for displaced people.

**Conclusions**

The green building design presented in this paper incorporates a variety of ecological design principles applicable to the tropical climate in central Haiti. The simplicity and inexpensive costs associated with this design are representative of the clients to which we will provide our findings. The design is flexible in nearly every aspect to allow construction on a variety of landscapes and incorporation of as many or as little eco-technologies as desired. It is our hope that the people of Cange will find our work useful in constructing homes for themselves and for the incoming residents displaced by the earthquake.

**References**


Stouter, Patti. (March 15, 2010). Choosing Shelter for Hazardous Areas


