

An Analysis Of Biochar's Appropriateness And Strategic Action Plan For Its Adoption
And Diffusion In A High Poverty Context: The Case Of Central Haiti

by

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ABSTRACT

Haiti has witnessed high deforestation rates in recent decades, caused largely by the fuel needs of a growing population. The resulting soil loss is estimated to have contributed towards a decline in agricultural productivity of 0.5% -1.2% per year since 1997. Recent studies show the potential of biochar use through pyrolysis technology to increase crop yields and improve soil health. However, the appropriateness of this technology in the context of Haiti remains unexplored. The three objectives of this research were to identify agricultural- and fuel-use-related needs and gaps in rural Haitian communities; determine the appropriateness of biochar pyrolyzer technology, used to convert agricultural biomass into a carbon-rich charcoal; and develop an action-oriented plan for use by development organizations, communities, and governmental institutions to increase the likelihood of adoption.

Data were collected using participatory rural appraisal techniques involving 30 individual interviews and three focus-group discussions in the villages of Cinquantin and La Boule in the La Coupe region of central Haiti. Topics discussed include agricultural practices and assets, fuel use and needs, technology use and adoption, and social management practices. The Sustainable Livelihoods framework was used to examine the assets of households and the livelihood strategies being employed. Individual and focus group interviews were analyzed to identify specific needs and gaps. E.M. Rogers' Diffusion of Innovations theory was used to develop potential strategies for the introduction of pyrolysis technology.

Preliminary results indicate biochar pyrolysis has potential to address agricultural and fuel needs in rural Haiti. Probable early adopters of biochar technology include households that have adopted new agricultural techniques in the past, and those with livestock. Education about biochar, and a variety of pyrolysis technology options from

which villagers may select, are important factors in successful adoption of biochar use. A grain mill as an example in one of the study villages provides a model of ownership and use of pyrolysis technology that may increase its likelihood of successful adoption. Additionally, women represent a group that may be well suited to control a new local biochar enterprise, potentially benefiting the community.

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Chapter 1

INTRODUCTION

Agricultural productivity in Haiti has declined an estimated 0.5-1.2% per year since 1997 (IMF, 2008), exacerbating food security issues in the Caribbean nation and contributing to pervasive poverty and malnutrition. Globally, deforestation and resulting soil loss due to erosive processes are significant culprits of decreasing agricultural productivity. Demand for fuelwood is the primary cause for deforestation in Haiti (as in other developing countries) and has reduced tree cover to an estimated 1-2% of pre-Columbian stands (IMF, 2008). These pressures on natural resources have led to a decline in living conditions, contributing to poverty levels in Haiti that are among the highest in the world. Fifty-six percent of Haiti's population lives in extreme poverty, defined as less than US\$1 per person per day (IMF, 2008). Additionally, Haiti ranked 145th out of 169 countries in 2010 – the lowest in the western hemisphere – on the United Nations Development Program's (UNDP) Human Development Index (HDI), which measures wellbeing using a variety of standard of living indicators (UNDP, 2010).

Adoption of appropriate technology has the potential to contribute significantly to sustainable development in impoverished regions. For instance, adoption of treadle pumps, a cheap and efficient irrigation tool, increased incomes six-fold in Zambia due to improved agricultural productivity. It also resulted in additional multiplier effects through increased local employment in the manufacturing and sale of the pumps (Kay & Brabben, 2000). Similarly, biochar technology has the potential to increase agricultural productivity and provide an alternative fuel source, particularly in areas where deforestation rates are high and fuel wood is the primary source of fuel. A biochar pyrolyzer is a simple kiln that allows users to char biomass more efficiently than traditional burial methods. The resulting charred biomass is known as green charcoal if

used as a fuel or biochar if used as a soil amendment. When mixed with agricultural soil, biochar has been shown to increase crop yields by 30-100%, among other benefits (Blackwell, Riethmuller, & Collin, 2009).

Although new technologies such as treadle pumps and biochar have shown to be very effective in certain contexts, this does not imply that these technologies are likely to work well in the context of every developing country. An important reason underlying causes of failure is the lack of understanding of the context into which they are introduced on the part of the outsider. An understanding of a community's needs and gaps is a necessary first step to effectively introduce and diffuse a technology. Identification and engagement of early technology adopters may increase the likelihood that a community will successfully embrace a given technological intervention. Pitfalls exist, however, in the identification of appropriate technologies as well as their proper use and dissemination as a development tool.

The objectives of this thesis are to: 1) identify agricultural- and fuel-use-related needs and gaps in rural Haitian communities; 2) determine the appropriateness of biochar pyrolyzer technology in the study villages; and 3) develop an action-oriented plan for use by development organizations, communities, and governmental institutions to increase the likelihood of adoption. The Sustainable Livelihoods (SL) framework (DFID, 1999) is used as a conceptual basis for understanding local livelihoods pertaining to farming practices and fuel use. Rogers' (2003) diffusion of innovations theory is used to develop a plan of action to increase the likelihood of adoption and identify appropriate stakeholders as potential early adopters of biochar technology.

In conjunction with the efforts of Carbon Roots International, a development-oriented non-profit currently based in New York City, research for this thesis was conducted during the month of January 2011 in Haiti. Individual interviews and focus

groups employing participatory rural appraisal techniques were conducted in two villages in order to elicit information on agricultural practices, fuel use, technology adoption, and management practices. Findings are presented and analyzed in the context of the SL framework and technology adoption literature.

The results of this study are intended to be used to inform a plan of action and guide an organization intending to introduce and diffuse biochar pyrolyzer technology. The results of the interviews and focus groups indicate a need for a method to increase crop productivity and food security, while declining firewood availability and a preference for cooking with charcoal indicates a gap in cooking fuel access and capacity. Biochar pyrolysis is a potential innovation that may address these needs and gaps. To increase the likelihood of pyrolyzer adoption, potential early adopters must be identified and engaged. The data analysis conducted for this thesis uses E.M. Rogers' Diffusion of Innovations theory to suggest who some of these early adopters might be and how they might be engaged. The interviews and focus groups also reveal attitudes towards other kinds of technologies (such as use of radios, cell phones etc.) and past histories of technological adoption and associated institutions that have evolved to manage these new technologies. This information is then used to develop an action plan on technological adoption and diffusion.

The scope for potential extrapolation of this study's findings and recommendations for other regions of Haiti as well as other developing countries is limited by the following considerations. First, the representativeness of the study is limited by the small sample size due to time constraints in data collection. The representativeness of the sample groups could not be ascertained because of sparse local demographic data. Thus the responses reported here may not be representative of Haitian fuel use and agricultural practices as a whole. Second, this study focused only on an

assessment of needs and gaps with respect to fuel use and agricultural livelihoods. The effectiveness of biochar technology in improving livelihoods was not assessed.

The thesis is organized as follows. Chapter 2 reviews the theoretical framework employed as well as relevant background literature, including Diffusion of Innovations theory, biochar pyrolysis technology, fuel use and agricultural practice in Haiti, project execution in a high-poverty setting, and the role of women in development. Chapter 3 covers the research design process and methodologies used in data collection and analysis. Chapter 4 introduces the research findings organized by sections on agricultural practices, fuel use, technology adoption, correlation analysis, and management practices. Chapter 5 contains an analysis and discussion of the findings, including recommendations for action. Finally, Chapter 6 consists of concluding remarks with respect to the study's main objectives and recommendations for further research.

Chapter 2

THEORETICAL FRAMEWORK AND LITERATURE REVIEW

In this chapter, the theoretical framework employed in this thesis is discussed along with a review of pertinent literature. The Sustainable Livelihoods (SL) framework structures the understanding of different assets in the study villages and the identification of needs and gaps with respect to agricultural practices and fuel use. Diffusion of Innovations theory provides a basis for developing a strategy for the introduction of biochar pyrolysis technology with the intent of increasing the likelihood of its adoption. A review of relevant literature pertaining to agricultural practices and management, fuel use, technology adoption, and biochar pyrolysis technology follows.

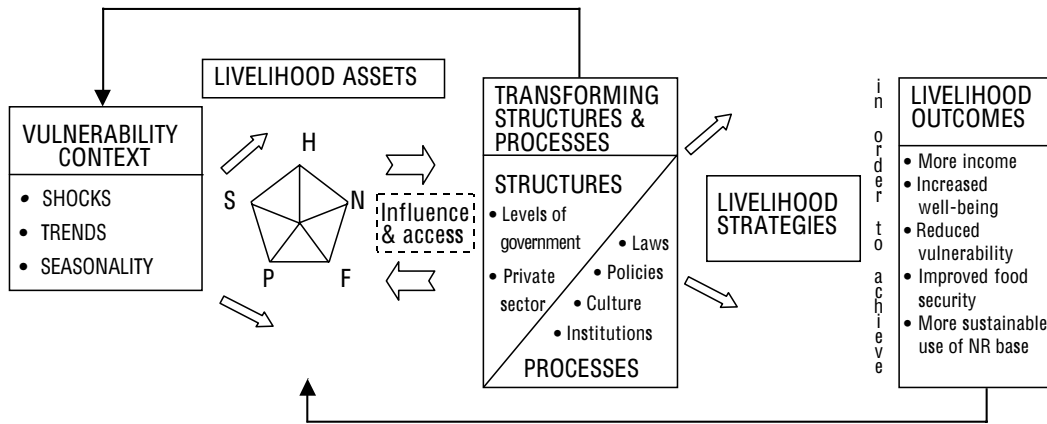
Sustainable Livelihoods Framework

The idea of “sustainable livelihoods” has become an integral part of many development practices and theories, beginning in the 1970’s (Chambers & Conway, 1991). Livelihood approaches allow for the conceptualization of economic activities in underdeveloped regions. The Institute of Development Studies, a global international development research organization, defines a livelihood as comprising “the capabilities, assets, and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from shocks, maintain or enhance its capabilities and assets, while not undermining the natural resource base” (Scoones, 1998, p.34).

The SL framework is used to understand people’s livelihoods, especially those in impoverished regions. The framework categorizes five forms of livelihood assets in the context of different forms of capital, including human, natural, financial, social, and physical, all represented in an “asset pentagon” (Figure 1) (DFID, 1999). The different assets, or sources of capital, are understood within the context of influence and access to

various transforming structures and processes (such as available technologies, markets, institutions, policies and culture). Given a household's assets and the technological, institutional, and cultural context within which it is placed, it may have a certain set of livelihood strategies available to it. These strategies, placed within the context of vulnerability to various shocks across different scales - ranging from local to regional, and various timelines, from short-term to long-term - translate into certain livelihood outcomes (see Figure 1). The usefulness of SL framework lies in pointing to a whole range of options for intervention that can be employed by an external agent/organization with the intent of improving livelihood outcomes. These may be in the form of improving the asset base (through increased capital assets or skill-building), or improving access to markets or new technologies.

Figure 1. Sustainable Livelihoods framework.



Key: H=Human, N=Natural, F=Financial, P=Physical, S=Social Source: DFID 1999

The SL framework is practical within the context of this study because it can be used to structure the understanding of needs and gaps in the study villages with respect to agricultural assets and practices, fuel use, technology adoption, and management practices. Additionally, the SL framework is action-oriented in that it identifies specific strategies to achieve certain livelihood outcomes. These strategies help to inform the

plan of action for biochar pyrolysis adoption. Finally, the SL framework uses a holistic approach to describe households within a given community, identifying inter-linkages between assets and livelihoods, and transcending levels (both contextual and in an interdisciplinary analysis). This results in both a broad and deep ability to understand a community's needs and gaps as well as identify appropriate points of intervention in the form of outcome-oriented livelihood strategies.

Adato and Meinzen-Dick (2002) identify three ways in which the SL framework may be adapted for agriculturally based research: within the context of vulnerability; influences on the assets; or, as part of policies, institutions, and processes. They identify adoption of new technologies as an influential factor with respect to the asset base. Potential barriers to technological adoption within the SL framework exist. A study in Mexico showed farmers choose to not plant improved maize strains because they are perceived to require higher costs for fertilizer, i.e. increased financial capital (Adato & Meinzen-Dick, 2002). Additionally, it was found that resource-poor farmers in Kenya were prevented from adopting technologies that allowed them to improve their soil quality due to a lack of land and labor, i.e. natural and human capital (Adato & Meinzen-Dick, 2002). Natural capital in the form of available land is identified one of the primary limiting factors to adoption of soil-improving technologies in the developing world (Adato & Meinzen-Dick, 2002).

Diffusion of Innovations

The theory of Diffusion of Innovations, developed by Everett M. Rogers (2003), posits that an innovation must acquire a critical mass of adopters to achieve a point at which the adoption of the innovation sustains itself without outside intervention. Prior to this critical mass being achieved, however, some systematic intervention to induce initial

adoption by innovators must take place. Innovators, defined as the initial 2.5% of adopters, are generally those with sufficient wealth to enable risk-taking ventures and access to ideas beyond the rest of the community's ability, and/or those who have in the past deviated from societal idea-adoption norms and have acquired an innovation that others have yet to adopt. They "play a gatekeeping role in the flow of new ideas into a system" (Rogers, 2003, p. 283).

Diffusion theory identifies critical factors that affect the adoption of innovations. These factors are divided into four broad elements: the innovation, communication channels, time, and the social system. The innovation itself can be categorized based on five perceived attributes: *relative advantage* over other ideas, *compatibility* with existing activities, the *complexity* of use, *trialability*, or the ability to experiment with the innovation, and *observability* of the results of use (Rogers, 2003). Communication channels are the methods through which people learn about new ideas and innovations. The time element can be broken into adopter categories, including the innovators, early adopters, early majority, late majority, and laggards. A social system is a cohesive community unit pursuing common interests.

Based on the "epidemic" model of technology diffusion, a significant barrier to initial adoption of a technology is insufficient information about the technology (Geroski, 2000). This barrier is common in the developing world where information channels are not as efficient. People lack access to efficient information pathways, and thus are slower to adopt new technologies. Lack of choice with respect to new technologies can also be a barrier to potential adoption (Geroski, 2000). When presented with only one version of a technology that does not allow for adaptation to specific needs and conditions, people are less likely to adopt it than if they were given several variations from which to choose.

A lack of understanding of needs and gaps as well as norms within a community can hinder a diffusion strategy. The example of attempted diffusion of the practice of water boiling in Peru as an innovation to curb water-borne disease illustrates the importance of understanding a community. Despite a two-year effort to encourage water-boiling through germ and bacteria education, Peruvian villagers declined to adopt the innovation. Germs and bacteria were inconceivable to the villagers and as the adoption campaign focuses solely on these attributes, no advantage was perceived and adoption failed (Rogers, 2003). A more comprehensive understanding of the community's beliefs and norms would have aided the water-boiling campaign to be more effective in the context of local knowledge (Rogers, 2003).

Rogers (2003) suggests the appropriateness of a technology for adoption in a developing country may be judged by a series of criteria laid out by Bordenave (1976) for planning social programs intended to result in a more just social structure. In the context of developing nations, the primary issues raised by these criteria are questions of equity: will the adoption of the innovation be hindered by a lack of equity and will the innovation contribute to inequity? Social structures, including equity of land ownership, are shown to have a fundamental bearing on the diffusion of innovations, with a lack of equity acting as a significant barrier (Bordenave, 1976).

Biochar Pyrolysis Technology

Pyrolysis, or heating of biomass in a near oxygen-free environment, results in a carbon-rich charcoal (Brown, 2009). This is called "green charcoal" if used as a fuel source, such as for cooking, as it is carbon neutral if the biomass input is from agricultural waste (Lehmann & Joseph, 2009). Alternatively, the resulting charcoal is called "biochar" if used as a soil amendment. When applied to soil and combined with

small amounts of compost, biochar aids water retention, improves cycling of nutrients, develops organic nutrients, and decreases soil acidity, resulting in a 30-100% increase in crop yields, a much larger increase than compost use alone (Blackwell et al., 2009; Laird, 2008). Additionally, the amendment of soil with biochar removes 50% of carbon in charred biomass from the global CO₂ cycle (Lehmann, Gaunt, & Rondon, 2006). With a half-life of ~1,000 years, this is considered a form of carbon sequestration (Lehmann et al., 2006).

Use of biochar dates back to pre-Columbian cultures in the Amazon basin, where farmers used slash and char techniques to create dark earth soils, known as Terra Preta (Sombroek et al., 2003). Over 500 years after the initial creation of these Terra Preta soils, farmers continue to value them for their increased nutrient content and soil properties, resulting in improved plant growth (Glaser, Lehmann, & Zech, 2002).

Biochar's effectiveness has been shown in a variety of environments. Sandy soils of the southeastern United States amended with biochar over a 67-day period showed "significant fertility improvements" due to increased soil pH, organic carbon, calcium, potassium, and phosphorus (Novak et al., 2009). Application of biochar to soils at ten sites in Laos was shown to have the potential to increase rice grain yields using traditional farming methods (Hidetoshi et al., 2009). A survey of 12 studies on biochar's impacts on crop yields when used as a soil amendment (Table 1) shows an increase in yields in all cases except for the instances of biochar overuse by Kishimoto and Sugiura (1985) (Sohi, Lopez-Capel, Krull, & Bol, 2009). The average increase in biomass after addition of 0.5 tons per hectare (Mgha-1) of biochar to the soil was ~170%, with a high of 244% and a low of 122%. Depending on soil type, additions of biochar at 5 tons per hectare and above can decrease biomass yields. Additionally, biochar appears to be most effective in highly degraded soils.

Table 1. Summary of biochar yield studies.

Authors	Study outline	Results summary
Iswaran et al. (1980)	Pea, India	0.5 Mgha-1 char increased biomass 160%
Iswaran et al. (1980)	Mung bean, India	0.5 Mgha-1 char increased biomass 122%
Kishimoto & Sugiura (1985)	Soybean on volcanic ash loam, Japan	0.5 Mgha-1 char increased yield 151% 5 Mgha-1 char decreased yield to 63% 15 Mgha-1 char decreased yield to 29%
Kishimoto & Sugiura (1985)	Sugi trees on clay loam, Japan	0.5 Mgha-1 wood charcoal increased biomass 249% 0.5 Mgha-1 bark charcoal increased biomass 324% 0.5 Mgha-1 activated charcoal increased biomass 244%
Chidumayo (1994)	Bauhinia trees on alfisol/ultisol	Charcoal increased biomass by 13% and height by 24%
Glaser (2002)	Cowpea on xanthic ferrasol	67 Mgha-1 char increased biomass 150% 135 Mgha-1 char increased biomass 200%
Lehmann (2003)	Cowpea planted in pots and rice crops in lysimeters, Brazil	Biochar increased biomass production by 38 to 45%
Oguntunde (2004)	Comparison of maize yields, Ghana	Grain yield 91% higher, biomass yield 44% higher on charcoal site than control
Yamato (2006)	Maize, cowpea, and peanut trial in area of low soil fertility	Increased maize and peanut yields, but not cowpea
Chan (2007)	Trial on radish yield using biochar without N	100 t ha ⁻¹ increased yield 300%
Rondon (2007)	Enhanced biological N-2 fixation by common beans, Colombia	Bean yield increased 46% and biomass increased 39% over control
Steiner (2007)	Four cropping cycles with rice and sorghum	Charcoal with manure resulted in highest crop yield
Kimetu et al. (2008)	Mitigation of soil degradation and comparison of maize yields, Kenya	Maize yield increased 200% in highly degraded soils

Source: Adapted from Sohi et al. 2009

Two broad types of pyrolysis exist, fast and slow, and vary in temperature of the pyrolysis process and the resulting products as outlined by Table 2. The percentages in Table 2 are percentage of total initial feedstock mass. Pyrolyzers may be constructed in a variety of techniques, many of which are still being field tested. Popular small-scale models include the “top lit up-draft”, or TLUD, as well as biochar stoves that simultaneously produce small amounts of biochar and heat that can be used to cook food. A double-barrel pyrolyzer constructed by Carbon Roots International in one of the study villages had a total construction cost of US\$40.00 using materials purchased in Port-au-Prince, the capital city of Haiti, and is described in more detail in Chapter 3.

Table 2. Comparison of pyrolysis processes by percentage of initial feedstock mass.

Process	Liquid (bio-oil)	Solid (biochar)	Gas (syngas)
Fast Pyrolysis ~500 ⁰ C Short residence time	75%	12%	13%
Slow Pyrolysis 300-450 ⁰ C Long residence time	30%	35%	35%

Source: Adapted from Sohi et al. 2009

Pyrolyzers exist in batch and continuous models. Batch models are generally smaller and more simple, such as TLUD and double-barrel pyrolyzers, are less efficient, and can only do one round of biomass pyrolysis at a time. Continuous pyrolyzers are able to take in a constant input of biomass and continuously convert it to biochar. An example of a continuous pyrolyzer that currently exists in one of the study villages is shown in Figure 2. This model is an open-source design by All Power Labs of Berkeley University called the Biochar Experimenter’s Kit, or BEK. An auger feeds biomass from an upper hopper (large barrel at top of Figure 2) into a central reactor where it is heated in a low to zero-oxygen environment. The BEK allows for a variety of fuel sources, including an

external propane tank and the syngas produced by the pyrolysis of the biomass itself. A second auger removes the charred biomass from the bottom of the reactor and into a separate receptacle.

Figure 2. Photo of Biochar Experimenter's Kit continuous pyrolyzer.



Source: All Power Labs

The TLUD, a batch pyrolyzer model, is shown in Figure 3. This pyrolyzer also exists in one of the study villages. As the name top lit up-draft implies, the fuel is lit at the top and air is sucked upwards. Compared to the BEK pyrolyzer, it is simple and cheap to construct. It is made from 55-gallon drums, which act as a kiln for the biomass, and has a chimney on the top that acts as an afterburner. A single batch can take one to one-and-a-half hours depending on the biomass, and results in approximately 20 to 30 pounds of charred biomass, or biochar.

Figure 3. Photo of TLUD pyrolyzer in study village.



Source: Photo by Eric Sorensen

Current barriers to widespread adoption of biochar pyrolyzers in impoverished regions appear to be predominantly technological. An efficient small-scale method of biochar production via efficient recycling of pyrolysis gasses has yet to be achieved and has significantly hindered adoption in the developed world (Lehmann, 2007). Similarly, a sufficiently affordable yet efficient pyrolyzer has yet to be introduced to the developing world, where affordability is a primary barrier to ownership of a technology. Many variations on biochar pyrolysis technologies exist, however attempts at the creation of a pyrolyzer intended for use in impoverished rural areas of the developing world have only begun recently. Studies on long-term effects of biochar on soil structure are lacking, and are limited chiefly to those of the Amazonian dark earth (Sohi et al., 2009).

Previous Attempts at Dissemination of Biochar Pyrolysis Technology

Current studies on biochar pyrolysis technology's potential as a development intervention are somewhat limited in scope, and concentrate primarily on crop yields and biochar's ability to sequester atmospheric carbon. Little research has been done to analyze specific technology adoption and dissemination methods beyond the donation of small-scale pyrolyzers or raw biochar to farming households by non-profit entities. Most studies concentrate on biochar's effect on crop yields rather than on the local economic and social impacts of biochar.

Several organizations exist with missions of distributing pyrolyzers and facilitating the adoption and use of biochar. SeaChar's Estufa Finca project has partnered with organic coffee farmers in Costa Rica to provide women with simple biochar-producing stove units (IBI, 2011). Operations are still in pilot phase, however, with local production and distribution developing through donations. Pro-Natura, one of the first non-profit organizations to work with green charcoal production in the 1980's, began a biochar production and education project in Senegal in 2008, and results have predominantly concentrated on the effects of biochar on soil and emissions reductions (IBI, 2011).

UB International, a non-profit organization, has developed two biochar-related community development projects in Mongolia and Thailand. Both are based on a model of distribution of simple biochar producing ovens to rural farmers and partnership with local non-profits to facilitate community engagement (IBI, 2011). Both projects, however, are still in pilot phase and are determining proper technologies for distribution, and have yet to scale up operation beyond several communities.

Each one of these projects is engaged in the distribution of biochar pyrolyzers and agricultural education as relates to the use of biochar. They are in the early phases of

operation and as such do not report on specific distribution methodologies or related successes and failures. Improvements in soil and crop yields by weight are reported across the board, but are limited in information as they are without any specific values. Determining the appropriate pyrolysis technology in a rural, impoverished setting is a common thread throughout biochar implementation projects.

Major international biochar organizations, such as the non-profit International Biochar Initiative, exist to support knowledge creation and sharing about biochar's use and potential applications, as well as to act as a forum for biochar-related projects across the world. Commercial biochar operations exist in the developed world, such as Biochar Solutions, which constructs and sells large-scale continuous pyrolyzers in the United States for use by university and governmental research groups.

Fuel Use and Agricultural Management in Haiti

Together, firewood and charcoal supply 1,974 tonnes of oil equivalent, or 66% of Haitian energy use – 71% of which serves residential needs, such as cooking (IEA, 2009). Firewood and wood destined for charcoal production are collected by family members, and make up the fuelwood economy. Unlike many developing countries, Haitian land ownership is not necessarily concentrated in the hands of the elite and is relatively evenly distributed, thus most people are able to gather fuelwood on their own property (Stevenson, 1989). Production of charcoal and use of charcoal and firewood is generally wasteful as a result of inefficient production methods and cooking technologies, resulting in increased consumption of fuelwood (Hosier & Berstein, 1992). As shown in Figure 4, charcoal is predominantly made in rural areas and sold at local markets for transport to and use in larger cities (Stevenson, 1989).

Fuelwood consumption, coupled with the expansion of agriculture into wooded areas, has resulted in massive deforestation in Haiti. The International Monetary Fund (IMF) estimated that in 2008 approximately 1-2% of Haiti's original forest cover remained. Figure 5 shows a hillside adjacent to one of this study's villages and depicts the extent of deforestation exposing bedrock due to soil erosion, despite the presence of vegetation in the agricultural valleys. Continued deforestation coupled with a growing population's demand for fuelwood puts greater pressure on remaining forest stands, while making fuelwood more and more difficult to collect.

Figure 4. Photo of charcoal for sale at Haitian market.



Source: Photo by Eric Sorensen

Since independence in 1804, Haitian land ownership has been regulated by a successive inheritance system resulting in the vast majority of peasants owning their own land plots that become smaller and more fragmented with each generation (Smucker, White, & Bannister, 2002). Various national surveys indicate between 53-66% of rural

Figure 5. Photo showing deforestation on hill slopes adjacent to study village.

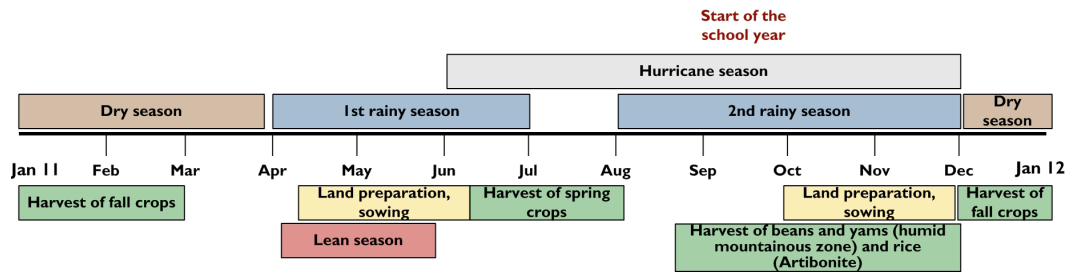


Source: Photo by Eric Sorensen

peasantsown land, while others practice sharecropping or rental of land (Smucker et al., 2002). Land is a primary capital asset, as cash resources are rare (Smucker et al., 2002). Agriculture in Haiti is generally a labor-intensive activity, with most rural families primarily engaged in farming (Smucker et al., 2002).

Haitian farming schedules cater to the wet and dry seasons. Figure 6 shows an approximate representation the seasonal planting and harvesting schedule, with two major planting seasons, one in spring during the first rainy season, and one in fall during the second rainy season. Harvesting is done for roughly two to three months after planting. In many regions, a third and even a fourth planting season exist between the two planting and harvesting seasons shown. These consist of smaller regional crops, such as fruits and tubers.

Figure 6. Haitian seasonal farming calendar.



Source: FEWS NET 2011

Past attempts at improving agricultural practices through technological adoption have shown mixed success. Hedgerow cropping with interspersed legumes has been shown to be generally widely accepted since 1981, and has resulted in increased soil nutrients and soil retention (Bannister & Nair, 1990). Many attempted agricultural interventions have been considered failures, however, because the resulting adoption patterns have been patchwork and inconsistent (Bannister & Nair, 1990).

Role of Women in Development

Women play an integral role in Haitian agriculture, and are closely involved with both planting and harvesting. Additionally, women and children in rural Haitian areas do much of the fuelwood gathering. Although women are an essential part of the household, they are often marginalized. They can, however, potentially be employed in a biochar pyrolysis technology adoption enterprise due to their close connection and involvement with both the agricultural process and fuelwood gathering.

When empowered through financial resources and education, women are shown to invest more in their family and community's wellbeing. When provided with financial opportunities, women are more likely than men to invest in education for themselves and their children, marry later, and have fewer children, thus spurring more widespread economic growth (Mills, 1999; Kristof & WuDunn, 2009).

When women are engaged directly by projects attempting to alleviate poverty in developing countries, the projects have a greater success rate (Tinker, 1990). These successful projects engaged women at all stages of development and execution, ensuring their knowledge is used. Many development projects tend to see women “as passive recipients of change” rather than as efficient agents of change they are, who open up opportunities for coming generations (Rowbotham & Mitter, 1994, p. 4). Women in Tanzania have, in fact, been shown to be more likely to show entrepreneurial behavior than men during times of economic hardship, resulting in further economic benefit to their households (Rowbotham & Mitter, 1994).

A large disparity between opportunities for men and women exists in Haiti, and may play a factor in Haiti’s continuing poverty. For example, 42 percent of women are illiterate, versus only 39 percent of men (IMF, 2008). This discrepancy excludes women from many professions other than low-skilled jobs – women represent only 32.3 percent of people employed in administrative positions in Haiti (IMF, 2008). As a whole, these disparities and lack of opportunities for women may hinder the Haiti’s economic development.

Project Execution in High-Poverty Context

An objective of this study is the development of an action plan for technological diffusion, thus project execution is an integral aspect. Successful community projects must include the following characteristics; they must be: impact oriented, measurable, time limited, specific, and practical (Margolius & Salafsky, 1998). These characteristics are intended to facilitate the execution of community-based projects and increase the likelihood of project success as outlined by Table 3. These guidelines aid the development of projects and help project developers avoid usual pitfalls.

A common methodology of project execution within the context of high-poverty communities involves non-governmental organizations (NGOs) or other implementing organizations trading responsibilities of executing small tasks with the community thereby leading to the completion of the project. This method, known as “playing catch with the community” by Orr (1985), requires a clear delineation of responsibilities between the implementing organization and the community. It is a useful technique as it builds trust between the organization and community and requires effort and interest on both sides. Additionally, as it is a step-based approach to project execution, it allows for flexibility when presented with unforeseen circumstances providing a framework that can be adapted easily.

Table 3. Community project success metrics.

Characteristic	Meaning
Impact Oriented	Project should have specific intended consequences for the community in question.
Measurable	Project should have specific intended consequences for the community in question
Time Limited	The village must see results within a reasonable timeframe
Specific	The village knows what the project intends to do so that they may understand and recognize eventual results
Practical	Project results must be applicable and appropriate to the needs of the village

Source: Margolius & Salafsky 1998

Project design and execution must take into account local factors and be tailored to the specific community-based project (Milehčic et al., 2009). Costs passed on to the community must take into account the local economic capacity. All necessary materials should be locally available and familiar to the community members. Community involvement must be present in all aspects of the project to ensure the project practicality requirement as outlined above by Margolius and Salafsky (1998).

Several important external factors exist with respect to the development and execution of a successful community-based project (Mihelcic et al., 2009). A national legal framework must be in place that allows the community to collectively make its own decisions. Continued institutional support must be in place, commonly in the form of site visits to communities by an NGO, agency, or other organization implementing the project after completion. This also must take the form of continued technical support with respect to the intended project's continued implementation.

Clearly defined operations and maintenance must be ensured by the organization implementing a community-based project (Mihelcic et al. 2009). Daily operative practices of the project must be developed with the community to ensure smooth daily functioning, as well as proper handling of tools to ensure longevity of the project. Long-term maintenance must be accounted for through preventative measures that help avoid breakdowns or other issues, through corrective measures when small breakdowns or issues arise, and through crisis measures when catastrophic problems arise.

To increase the likelihood of long-term project success in the context of high-poverty communities, the community's management capacity must be improved. Specifically, participatory control and education should be incorporated into a project's execution to catalyze long-term change and development results (Davis and Garvey 1993). Improved community management capacity will allow for future project flexibility, as varying conditions may change the community's needs. Additionally, if the project is indeed successful, the need for the specific iteration of that project may diminish, requiring either alteration of the project or a new project altogether.

Chapter 3

RESEARCH DESIGN AND METHODOLOGY

Data collection methods for this study were based on participatory rural appraisal techniques, individual interviews, and group discussions conducted during a three-week period in January 2011 in the La Coupe commune of Haiti's Centre department (Figure 7). The villages of La Boule and Cinquantin in the La Coupe region were selected based on variability in accessibility, population size, infrastructure, economic activities, and prior knowledge of biochar pyrolysis technology (See Table 4 for a comparison of the two study villages). Initial contact had been made previously with the village of Cinquantin in September 2010, and villagers had indicated an interest in biochar pyrolysis technology during informal discussions and interviews. This initial communication determined Cinquantin as a study village due to potential interest in biochar technology, and thus a potentially increased possibility of biochar technology adoption. As La Boule is near Cinquantin, but differs from the latter in that the community had no prior knowledge of biochar, it was selected as a control village that would allow for an unbiased local comparison of the potential of biochar technology.

La Boule (population ~950) is accessible via a primitive road, and thus is reachable by means of public and private transportation (Figure 8). The village is located approximately 30 kilometers due north of Port-au-Prince. However travel time can range from 3 hours to 10 hours depending on the season and the condition of the road. A weekly market occurs in the center of La Boule, which also boasts two churches, two schoolhouses, a diverse economy that includes wood-workers, shop keepers, garment repair, metal working, and employment by non-governmental organizations. The population of La Boule was not familiar with biochar pyrolysis technology prior to this study.

Table 4. Comparison of two study villages.

	La Boule	Cinquantin
Population	~950	~450
Transportation access	Primitive road	Foot, pack animal
Weekly market	Yes	No
Dominant economic activities	Farming, small-scale businesses	Farming
Knowledge of biochar use	No	Yes

Source: Interview data and observation

Cinquantin (population ~450), accessible only by foot or pack animal, is approximately three kilometers northwest of La Boule (Figure 8), and has a single-room schoolhouse cum church. Economic activities are limited to subsistence agriculture and charcoal production for sale at nearby markets. A simple double-barrel pyrolyzer (Figure 9) was constructed in Cinquantin in September 2010 by Carbon Roots International and has seen intermittent use by some of the population.

Figure 7. Map of Haiti; La Coupe region is marked with a pin ~30 kilometers north of Port-au-Prince.



Source: Google Earth

Figure 8. Map of central Haiti; La Boule and Cinquantin villages are indicated with pins.



Source: Google Earth

Figure 9. Photo of pyrolyzer constructed in September 2010 in Cinquantin.



Source: Photo by M. Ryan Delaney

The Cinquantin pyrolyzer was constructed from three 55-gallon steel drums and some sheet metal. The lid from the first drum was removed and approximately 2 inches were cut from the top to shorten the entire drum. The second drum's top and bottom were removed, and a vertical cut was made along one side to open the drum. An approximately 30-cm-wide section from the third drum was spliced into this section, resulting in a drum with a larger diameter into which the first drum could fit. Two lids were constructed out of spare sheet metal: the first was fixed to the bottom of the larger outside barrel, while a chimney was constructed out of the remaining scrap from the third barrel and fixed to the second lid, acting as a removable top. Several ventilation holes were added to the bottom sides of the outside barrel to allow oxygen flow.

Three attempts at biochar production were made using dried and discarded cobs, stalks, and husks from maize. The inner barrel was filled with this maize biomass, and placed upside-down in the outer barrel. The space between the inner barrel and outer barrel wall was filled with dry, easily-combustible biomass such as husks and small twigs. The biomass in the outer chamber was ignited and allowed to burn for several minutes before the lid with the chimney was placed on top. As the biomass in the outer chamber began to heat up the biomass in the inner chamber, syngas was produced and released into the outer chamber, fueling the process of heating and charring the inner biomass. After approximately 2-3 hours the process was complete, resulting in 20-30 pounds of biochar from the inner chamber.

Study participants were selected with the intent of creating a representative cross-section of Haitian demography and included elements such as age, employment type, and gender. Demographic indicators included age cohort and gender. Data from the individual interviews was analyzed using SPSS statistical analysis software. Qualitative data collected via participatory rural appraisal (PRA) techniques and focus group

discussions was synthesized and analyzed. Demographic data from the most recent Haitian census was used to ensure the representativeness of participant sample groups. Selection of study participants was performed with the intention of characterizing the wider Haitian population so conclusions reached in this study might be generalized to the extent possible. As employment type in Cinquantin is predominantly agriculturally-based, this was not a primary factor in selection of participating households in this village. Additionally, the small sample size of households interviewed in this study limits the representativeness of the study's results. PRA techniques were employed to address this potential limitation, with the intention of engaging a wider audience within the two villages.

PRA techniques, popularized by Robert Chambers during the 1990s, comprise novel approaches to gathering knowledge and information from local peoples (Chambers, 1994a; Chambers, 1994b). In contrast to traditional survey questionnaire practices, PRA methods encourage collective knowledge sharing through participatory activities such as mapping of local resources, creation of seasonal calendars depicting activities, and daily observation. PRA is advantageous as it empowers participants to share local knowledge collectively deemed pertinent to the functioning of community systems, producing information that might not otherwise have been elicited through traditional survey methods. PRA was selected for this study due to these valuable attributes, as well as its capacity to bring forth large amounts of information in a relatively short period of time and at low-cost.

In Cinquantin, four different PRA activities were performed: a transect of the community and surrounding areas highlighting land use and resource access; the assembly of a local map by community members using available materials emphasizing resource use, land use, and infrastructure; discussions with separate groups of men and

women indicating daily activities during different seasons; and conversations with separate groups of men and women specifying access and control over community resources (see Appendices A and B). Groups ranged in size from four to 25 individuals with variation in number due to availability of participants and their perceived interest in each activity. PRA groups were organized to be representative and ensure that women and men were both equally represented.

In addition to PRA techniques, individual interviews were conducted with the intention of eliciting more focused data. Survey questions (see Appendix A) concentrated on three categories: local agricultural practices, fuel production and use, and technology use and adoption. A total of 30 individual interviews were conducted, 20 in Cinquantin and 10 in La Boule. Participants were selected based on their willingness to participate and with the intention of providing a representative sample based on demographic indicators.

Three group discussions concerning agricultural practices, fuel use, and technology adoption were conducted in both Cinquantin and La Boule (see Appendix B). Group sizes ranged from five to 11 participants. Group discussions highlighted specific knowledge pertaining to each subject, such as agricultural assets and practices, fuel use, and technology adoption, while allowing for group consensus to be attained.

All PRA activities, individual interviews, and group discussions were conducted with the approval of the Arizona State University's Institutional Review Board (IRB). Prior to any interview, activity, or discussion, the researcher solicited the consent of the participants and provided them with knowledge of the study's scope and purpose, as well as their rights as a participant, by providing them with an IRB-approved document (see Appendix C). The minimum age of participants was 18 years.

Data collected from individual interviews were analyzed using SPSS statistical analysis software. SPSS allows for determination of statistical significance in correlations between variables. Pertinent questions from individual interviews were translated into specific variables within the context of the SPSS software. This allowed for statistical analysis of the variables and the relationships between variables, including the identification of statistically significant linear-dependence correlations between variables by computing Pearson coefficients. Focus group discussions were translated from Haitian Creole to English and transcribed, permitting in-depth insights into community members' perceptions and practices.

Chapter 4

FINDINGS

The findings discussed in this chapter are intended to report on the needs and gaps of the villages of Cinquantin and La Boule with respect to agricultural practices and assets and fuel use. It also identifies potential adoption strategies for a new agricultural technology-based intervention.

The findings are divided into five sections: agricultural assets and practices, fuel use, technology adoption, correlation analysis, and management practices. Survey data is represented in tables and in text when appropriate. These data are supported qualitatively by quotations from villagers of Cinquantin and La Boule. The findings in each section are examined within the context of the SL framework to address the overall research questions. The management practices section is further divided into three sections: data on a mill in Cinquantin, the potential of a pyrolyzer in Cinquantin, and gender roles.

Agricultural Assets and Practices

This section presents agricultural practices of the villages Cinquantin and La Boule, and data representing potential needs, gaps, and challenges inherent in these practices. Table 5 summarizes selected responses based on individual face-to-face interviews conducted in the two villages. This data is then analyzed in depth and supported by quotes from local farmers for further insight into the practices.

Based on the interview responses, 75 to 80% of sample households own plots of land of variable size. In Cinquantin, 45% of respondents own less than a carreau of land (a carreau is a traditional Haitian unit of measurement equal to 1.29 hectares or 3.19 acres). Fifteen percent of respondents own between one and two carreaus of land, and 15% own more than two carreaus. In La Boule, 50% of respondents own less than a

carreau of land, 10% own between one and two carreaus, and 20% own more than two carreaus of land. The remaining sample households practice “demoitier,” a form of land- and labor-sharing in which landless families work the land of neighbors with larger plots for a share of the crop yield. One family in La Boule is able to support themselves solely through income derived by owning and running a small shop.

Both individual and group discussions as well as field observation indicate that a variety of primary food crops are grown on a rotational basis over the year. During the winter months, the driest of the year, black beans are grown; upon the arrival of the rains in the spring, maize is cultivated. In the slightly drier summer months, millet is grown; rice is planted during the fall when there is increased precipitation. Planting schedules are subject to change based on availability of rainfall in any given year. In addition to these primary crops, farmers may grow fruits, vegetables, and starches such as oranges, bananas, plantains, avocados, squash, okra, sugarcane, yams, potatoes, cassava, and pigeon peas. Figure 6 in Chapter 2 represents a generic Haitian planting schedule for comparison to these results.

In Cinquantin, survey responses indicate that 70% of sample households irrigate their fields through dug channels from the Mahotier, a minor stream in the area. The Mahotier’s source is located approximately 200m south of Cinquantin’s center and the stream flows through the village and the central fields. The village *Houngan*, or Vodou priest, regulates access to the stream’s water. The *Houngan* pays tribute to the stream’s *Lwa* (spirit) to ensure its continued flow. Villagers pay the *Houngan* a nominal fee to be entitled access the water. In spite of this arrangement, interviews and group discussions indicate water is seen as collectively owned. In contrast, La Boule is uphill from the nearest stream and has no easy access to water, thus only 13% of respondents indicated use of irrigation use while the rest relied on rainfall.

Traditional farming tools include the pick and the hoe, with all households in both villages reporting their ownership and regular use. Use of any additional farming tools appears to be uncommon, as less than 5% of interview participants indicated ownership and use of any farming tools of any kind other than a pick and a hoe.

Use of fertilizer is uncommon in both villages according to survey results, with only 19% of sample households reporting usage in Cinquantin and no usage reported in La Boule. Here, fertilizer is defined as any natural or chemical enhancement to soil, including manures. The reasons for not using fertilizer include a lack of knowledge in the use of fertilizer or manure, and the prohibitive cost of using any form of chemical fertilizer.

Table 5. Agricultural assets, perceptions, and practices in study villages.

	Cinquantin % (n=20)	La Boule % (n=10)
Households that own land	75	80
Households that have irrigation	70	13
Households that use fertilizer	19	0
Reason for not using fertilizer:		
Too expensive	54	50
No knowledge	46	50
Households that leave agricultural leftovers in field	78	100
What is done with leftovers:		
Burnt in field	56	28
Eaten by animals	56	86
Households reporting decreased crop yield during lifetime	94	80
Perceived reason for decrease:		
Less rain	47	43
Overworked land	40	57
Don't know	13	0

Source: Interview Data

As indicated in Table 5, 78% of households in Cinquantin report leaving crop leftovers on the field, while 100% of households in La Boule report the same practice. Informal discussions indicate that this practice is not perceived to impart any benefit to the agricultural process, and is primarily done because of its simplicity. These leftovers

are then burned by 56% of Cinquantin households and 28% of La Boule households. Additionally, 56% of households in Cinquantin report allowing animals, including livestock, to eat these leftovers, while 86% of households in La Boule allow animals to eat the agricultural leftovers. Animals owned by households include chickens, goats, donkeys, pigs, ducks, cattle, and horses. The livestock, and any other domesticated animals, are not used for plowing fields nor harvesting; they are kept chiefly as food sources and transportation.

When asked if, overall, crop yields had decreased in their lifetimes, 94% of respondents in Cinquantin and 80% of respondents in La Boule responded in the affirmative. Perceived reasons for this decrease included a lack of rainfall and overworked land. Overworked land, or “tired land,” when translated directly from Haitian Creole, is defined as soils that have decreased in nutrient content through anthropogenic practices.

The general trend of decreasing agricultural yields is illustrated by the following quote from an elderly farmer in Cinquantin reflecting back on crop productivity in his youth:

The ground was fertile. We used to grow big bananas, more yams... bigger yams, everything would grow bigger. We didn't need to plant, it would grow each year again. Now it's so hard to grow anything.

Another farmer from Cinquantin in his 40's describes why he believes this trend of decreasing agricultural yields exists:

The ground is too dry now. We can't grow anything because there is no water and the ground doesn't grow anything. Water was easy to come by... The rivers had more water, the springs had more water.

These quotes further corroborate results of the individual interviews in Table 1 and national statistics presented in Chapter 2 indicating a trend in decreasing crop yields and agricultural productivity.

In the context of the SL framework, data presented in this section on agricultural assets are considered part of the asset pentagon (Figure 1). Knowledge and use of fertilizer, practices involving agricultural leftovers, and perceptions of and potential reasons for decreases in agricultural productivity represent human capital, or skills and knowledge enabling various livelihood strategies described in Chapter 2. Fertilizer itself, however, is considered physical capital. Land ownership is considered physical capital, allowing for various livelihoods. Irrigation use represents physical capital, as it requires access to water, land, and proper tools. Construction and maintenance of irrigation canals is a livelihood strategy that is derived from the knowledge base and physical capital (part of the asset pentagon). The SL framework provides a context for understanding these forms of capital and how they fit together within the asset pentagon.

Fuel Use

In this section, fuel use practices of Cinquantin and La Boule are presented. Individual survey responses are summarized in Table 6, while data gleaned from group discussions further flesh out and facilitate an understanding of local fuel use practices. Important trends visible in the data include the prevalent use of wood as a cooking fuel, a decline in availability of trees, and a trend of increased charcoal production and use.

According to individual survey responses, use of wood as cooking fuel is prevalent with 100% and 90% of households in Cinquantin and La Boule, respectively, regularly preparing food with wood. Thirty percent of respondents from both villages report regular use of charcoal as a cooking fuel. Based on observations and informal

discussions, the most common method of cooking with wood involves the use of three stones of equal size, with a pot or pan placed on top and the firewood in between the three stones. Charcoal use, however, requires a more specialized stove apparatus, which must be purchased for approximately US\$15.00 at a local market and is not commonly owned.

Table 6. Fuel use practices and assets in study villages.

	Cinquantin % (n=20)	La Boule % (n=10)
Households that regularly use wood as fuel	100	90
Households that regularly use charcoal as fuel	30	30
Households that prefer wood to charcoal	10	40
Reason for preferring wood:		
Easier	100	100
Households that prefer charcoal to wood:	90	60
Reason for preferring charcoal:		
Less smoke	39	50
Faster	56	17
Food tastes better	6	0
No other option available	0	17
Charcoal represents a higher social status	0	17
Households that make charcoal	70	80
Households with increased charcoal use over lifetime	94	100
Fuel use per day (in fuelwood equivalent):		
Less than 1m ³	27	29
1 to 2m ³	47	57
More than 2m ³	26	14

Source: Interview data

Survey responses indicate an overall preference for charcoal over wood as a cooking fuel, with 90% of respondents from Cinquantin and 60% of respondents from La Boule preferring charcoal. The predominant reasons for this preference are a more pleasant cooking experience due to less smoke and shorter cooking times, but also include an improved taste of the food when it is grilled, a lack of trees from which to collect wood and thus no other alternative to charcoal, and a perception that charcoal carries a higher social status. Respondents who prefer wood to charcoal as a cooking

fuel state their preference is based on the ease and simplicity inherent in a wood-based cooking experience.

Charcoal production is a common activity, with 70% of respondents in Cinquantin and 80% of respondents in La Boule partaking in this endeavor. Reported charcoal usage is much lower, as previously noted, than charcoal production. Families engage in charcoal production predominantly to sell at local markets as a form of supplemental income. Production of charcoal falls to the men, who pile available wood into a mound that is then lit and covered by dirt and allowed to smolder for several days, charring the wood in a low-oxygen environment. The charcoal sold eventually reaches larger towns and cities, with the price marked up at each sale.

Survey responses and group discussions indicate an overall trend of increasing charcoal production and use during the lifetimes of community members. In Cinquantin, 94% of survey respondents indicate increased charcoal use, while 100% of La Boule's respondents report the same. When asked about cooking fuel use in his youth, a middle-aged farmer in Cinquantin responded:

[We used] wood. Before nobody used charcoal, they used regular wood. We cut it and used it to cook. Now things have changed, you don't see wood anymore, you use more charcoal.

This trend substantiates findings from other studies indicating increased charcoal use throughout Haiti, as shown in Chapter 2. According to informal discussions, reasons for increased charcoal use and production include a decreasing number of trees resulting in fewer opportunities to collect wood, charcoal being a more efficient use of the remaining wood for cooking, and a perceived need to offset lost income due to declining agricultural productivity with other income generating activities.

The preceding fuel use practices are placed into the context of the SL framework as forms of capital in the livelihoods assets pentagon. Access to firewood may be considered a form of physical capital. Knowledge and ability to produce charcoal from firewood is human capital. Understanding the data within the SL framework allows for the categorization of the forms of capital how the assets relate to each other.

Technology Adoption

In this section, technology ownership, adoption, and use data are presented based on individual survey results and focus group discussions. Results, shown in Table 7, indicate a majority of households own some form of modern technology. These findings are intended to illustrate potential gaps and needs of livelihood assets within the SL framework, as well as indicate potential adoption and ownership strategies for an agriculturally based technology.

Table 7. Technology ownership in study villages.

	Cinquantin % (n=20)	La Boule % (n=10)
Households that own any technology	65	90
Households that own the following technologies:		
Radio	60	80
Flashlight	55	10
Cell phone	20	30
Diesel generator	10	0

Source: Interview data

According to survey respondents, 65% of households in Cinquantin and 90% of households in La Boule report ownership of any “modern technology,” defined here as a tool that requires some form of electricity or fuel to perform. Responses indicated the most-common technology in both villages is the radio, with 60% and 80% in Cinquantin and La Boule, respectively, reporting ownership. Two households reported ownership of

diesel generators, the local Vodou priest and the schoolteacher, both of whom regularly hold community functions that carry on until after dark, necessitating artificial lighting.

A manually powered sewing machine, propane-oven bakery, and a forge are present in La Boule. All are individually owned, and community members may pay the owners for the services they render. The owners of these innovations use the technologies as supplementary sources of income in addition to farming. During an individual interview, the owner of the sewing machine reported he had learned of sewing machines in the 1970s from a friend who had emigrated to the United States, and purchased it in Saut d'Eau, a city located approximately seven kilometers east of La Boule. These examples represent technological innovations adopted by villagers in La Boule, providing a potential parallel to biochar pyrolyzer adoption.

Correlation Analysis

In this section, results of the statistical analysis using bivariate correlations are presented and displayed in Table 8. The table presents a matrix of bivariate correlations between ownership of tools, animals, technology, crops, and other resources. The numbers reported are: a Pearson coefficient (r), a statistical measure of the linear dependence between two variables, assuming values between -1 (negatively but strongly correlated) and 1 (positively and strongly correlated), and a two-tailed significance (p). Data for this analysis was the result of 30 individual interviews from both Cinquantin and La Boule.

Technology ownership is correlated to irrigation access and animal ownership, among other variables. A summary of notable significant correlations follows. A significant positive correlation between households that report owning cattle and those that report owning a flashlight exists ($r= 0.479$, $p= 0.008$). Additional correlations with

flashlight ownership exist, with flashlight and radio ownership showing a positive correlation ($r= 0.577, p< .001$). A positive correlation exists between households that own flashlights and grow rice ($r= 0.617, p< .001$). Households that report using fertilizer and households that own a flashlight show a positive correlation ($r= .411, p= .046$). Finally, households that own flashlights and those that have irrigation show a positive correlation ($r= .480, p= .010$).

Table 8. Bivariate correlations between selected variables in study villages. Fairly strong (>0.3) to strong (>0.5) correlations shaded gray (n=30).

	Owns horse	Owns any tech	Owns flashlight	Owns radio	Non-trad tools	Grows sugarcane	Uses fertilizer	Water from Citronier	Has irrigation
Owns animals	(.460, .012)	(.374, .045)	(.276, .147)	(.367, .050)	(.170, .377)	(.277, .180)	(.204, .350)	(.491, .009)	(.106, .598)
Owns cow	(.704, .000)	(.285, .133)	(.479, .008)	(.374, .046)	(.260, .172)	(.452, .023)	(.350, .100)	(.246, .216)	(.432, .024)
Owns flashlight	(.302, .111)	(.492, .006)	X	(.577, .001)	(.227, .227)	(-.093, .652)	(.411, .046)	(.167, .397)	(.480, .010)
Owns radio	(.191, .320)	(.853, .000)	(.577, .001)	X	(.131, .489)	(.010, .962)	(.267, .207)	(.258, .185)	(.579, .007)
Owns cell phone	(.370, .048)	(.333, .072)	(.354, .055)	(.223, .236)	(.337, .069)	(.088, .669)	(.364, .081)	(.302, .119)	(.137, -.487)
Non-trad tools	(.370, .049)	(.112, .556)	(.227, .227)	(.131, .489)	X	(-.072, .726)	(.552, .005)	(.333, .083)	(.179, .362)
Grows rice	(.185, .377)	(.458, .019)	(.617, .001)	(.566, .003)	(.133, .516)	(-.020, .922)	(.243, .253)	(.500, .009)	(.217, .287)
Uses fertilizer	(.168, .443)	(.243, .253)	(.411, .046)	(.267, .207)	(.552, .005)	(-.143, .505)	X	(.312, .138)	(.378, .069)
Has irrigation	(.515, .006)	(.362, .058)	(.480, .010)	(.579, .007)	(.179, .362)	(-.120, .558)	(.378, .069)	(.041, .835)	X
Agricultural leftovers	(.258, .223)	(.636, .001)	(.387, .056)	(.582, .002)	(.089, .672)	(.161, .442)	(.178, .417)	(.029, .890)	(.236, .256)
Uses charcoal	(.025, .896)	(.139, .465)	(-.199, .292)	(-.191, .311)	(-.070, .712)	(.435, .026)	(-.524, .009)	(.163, .408)	(-.198, .313)
Uses diesel	(.197, .306)	(.161, .395)	(.327, .077)	(.189, .317)	(-.050, .796)	(-.104, .612)	(.342, .102)	(.480, .010)	(.258, .185)
Community ownership	(.003, .987)	(-.275, .149)	(-.519, .004)	(-.271, .155)	(-.441, .017)	(-.297, .149)	(.411, .046)	(-.187, .351)	(-.503, .008)

(Pearson coefficient (r), significance (p))

Source: Interview data

Households that report owning horses show a significance positive correlation with: households that own cell phones ($r= .370, p= .048$); households that use non-traditional farming tools, defined as anything aside from a pick and a hoe ($r= .370, p= .049$); and, households that report using irrigation ($r= .515, p= .006$). Horses are uncommon, with only 20% of households reporting ownership. Radio ownership as reported by households correlates positively with those that grow rice ($r= .566, p= .003$).

Additionally, households that own radios and those that have irrigation correlate positively ($r = .579$, $p = .007$).

Broadly, technology ownership correlates strongly with animal ownership (especially cows and horses, which are more expensive) and irrigation and fertilizer use (evidence of past agricultural innovation adoption). Land ownership and technology ownership are relatively evenly distributed, as shown in the descriptive statistics, and are not strongly correlated, indicating possession of land is potentially not a strong constraint to ownership of technologies. Ownership of animals such as cows and horses is considered a proxy for wealth, while irrigation and fertilizer use are considered proxies for past innovation and interest in risk taking ventures, as well as technology adoption.

Management Practice

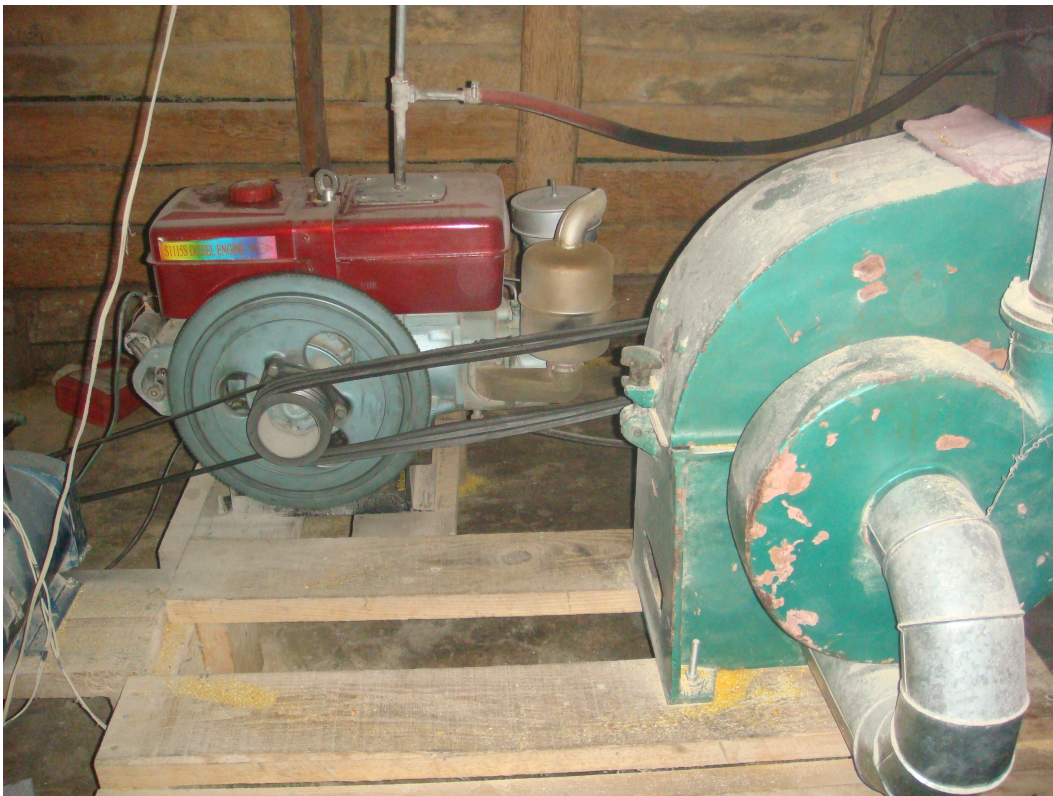
More advanced technology is somewhat uncommon in the La Coupe region, and the villages of Cinquantin and La Boule are not exceptions. Most families practice subsistence agriculture and have little access or means with which to purchase any more advanced technology beyond simple radios, flashlights, and sometimes cell phones. Haiti's electrical grid does not extend to the La Coupe region, and as such the only available electricity comes from individually owned diesel generators typically owned by more well-to-do community members.

Survey responses indicate perceived collective ownership of common resources, such as water, in Cinquantin. In addition, there appears to be a cultural practice of labor sharing of agricultural work, as respondents indicated a perceived collective ownership of labor demonstrated by sharing of work between neighbors and friends in the fields. This is in contrast to respondents in La Boule, who reported that nothing is owned by the community.

The mill in Cinquantin.

A small, diesel powered mill is located centrally in the village of Cinquantin (Figure 10). The mill provides a potential ownership and use model for a community-based biochar pyrolyzer, and is described in some detail here. It is unique to this village in that it is a privately-owned technology that is used by the majority of community members. Villagers use the mill to grind grains, which increases the product's value at local markets. The mill is housed in a large shed kept under lock and key by a caretaker. It is adjacent to the Mahotier stream where it passes through the center of Cinquantin. This easily accessible location attracts people from the entire region to the

Figure 10. Photo of mill in Cinquantin.



Source: Photo by M. Ryan Delaney

mill, some of whom walk for several hours. The mill is made available to villagers six days a week, and is usually shut on Sundays when people tend to spend more time with their families and rest.

A number of different mills have been present in Cinquantin since 1982, with only one functioning at any given time – as each breaks down, eventually a community member purchases another. The current mill was brought to the village in 2006. The mill is owned by a former villager who now divides his time between Port-au-Prince and Queens, New York, and visits La Coupe several times each year. The mill is maintained and regulated by a caretaker, hired and paid a weekly salary by the mill's owner.

For the cost of 5 Haitian gourdes (approximately US\$0.12) an individual may use the mill to grind one marmite (approximately 25 pounds) of grain on a first-come first-served basis. Survey responses indicate wide usage of the mill by villagers in Cinquantin, with 75% of respondents indicating use greater than three times per week. Usage appears to decrease with distance, as only 20% of respondents in La Boule – a roughly 30-minute walk from the mill – report use greater than three times per week. Grain is carried by hand or on the back of a donkey. The mill frequently breaks down due to lack of routine maintenance, such as regular oiling. During an informal discussion at the mill, a woman waiting her turn on the mill spoke about the difficulty of breakdowns:

The mill breaks down all the time! We have to walk all the way back home with our food, and we haven't done anything. You don't always know when the mill is broken before coming.

Mill breakdowns can be quite disruptive, as it prevents many villagers from efficiently using time previously allotted to milling their grains. Communication

channels are used to spread information about breakdowns, but are often incomplete and inefficient.

Potential biochar pyrolyzer unit in Cinquantin.

During group discussions concerning technology use, and after learning about potential uses for biochar pyrolyzers, villagers in Cinquantin were asked if they thought it might be useful based on their needs and what potential procedural steps might be taken to ensure its ease of use. The consensus reached by the group indicated that pyrolyzer technology would be of value to their community.

It was suggested by discussion group participants that the best location for a pyrolyzer would be an easily accessible, centralized place much like the mill's current location. Additionally, the women present in the group discussion volunteered themselves and their children for the task of collecting leftover crop biomass and bringing it to a central location for the pyrolysis process. A middle-aged woman expressed her willingness to participate during a focus group discussion:

My children and I, we would be very happy to bring in corn leftovers and other crops. We can do it when we come home from the fields. The kids will do it if we tell them to. And if we are paid for it, it will help us a lot.

As the woman mentioned, it was indicated that initially a small payment made to the individual per trip would be preferred by community members as an additional incentive to induce behavioral change.

Gender roles.

The process of producing and selling charcoal in Cinquantin and La Coupe is heavily influenced by traditional gender roles. Currently, wood is collected by both

genders and people of all ages, depending on who is available during the current season. This wood may either be used to produce charcoal or for cooking within the family. The men perform the task of charcoal production. After the men make the charcoal, the women are responsible for either using it to cook with or selling it at the local markets. Additionally, the task of transporting charcoal to and from the market, and purchasing charcoal at the market, belongs to women. Cooking, using both firewood and charcoal, is done by women. The majority of the fuel use and transportation is controlled by and geared towards women, as men participate only in the production of charcoal, and partly in the collection of fuel wood.

Many of the tasks of farming are shared between men and women, with men taking more labor-intensive roles. Men predominantly prepare the fields, while planting is shared between genders. Men maintain and care for crops during growth, and then the harvest and transportation of crops is shared between genders. Women play an indispensable role in many aspects of agricultural practices, and are intimately familiar with the entire process.

While the mill's owner and caretaker are both men, the role of processing grains at the mill in Cinquantin falls predominantly to women. Women carry grains to and from the mill, either by hand or on the back of a donkey. Women usually carry between 40 to 60 pounds of grain per trip by hand, more if a donkey is available. In addition to the task of milling grain, the mill serves as a social gathering place where women chat while waiting their turn to process their grains. Men are expected to maintain the mill and fix it when broken; however its everyday use for processing grain is primarily by the women of the community. The mill example not only provides a model for community-based pyrolyzer adoption, but also a potentially empowering role for women within a new biochar centered enterprise.

Chapter 5

ANALYSIS AND DISCUSSION

The findings presented in Chapter 4 are analyzed and discussed in this chapter. Needs and gaps are present in terms of agricultural and fuel use assets, indicated both by national level statistic as well as the results from interviews in Cinquantin and La Coupe. Biochar pyrolysis presents a potentially appropriate technological intervention to help address these needs and gaps. Based on interview findings, analysis, and technology adoption literature, potential early adopters of biochar pyrolysis technology are identified in addition to information diffusion models to increase likelihood of adoption. A potential model for an introduction strategy of biochar pyrolysis technology is the business model seen at the mill in Cinquantin. Finally, a plan of action is outlined for introduction and dissemination of biochar use.

Interview responses indicate a prevalent perception that agricultural yields have declined during the lifetime of respondents. This finding corroborates national statistics showing increasingly insufficient food production for Haiti's population. In addition, interview responses indicate a desire for an intervention to address declining yields. This lack of production can contribute to widespread malnourishment in Haiti, as outlined in Chapter 2, and represents a need for further food security in the form of more efficient and higher yielding agricultural practices.

Fuel use in the La Coupe region, like much of Haiti, is primarily dependent on firewood collection. Declining tree stands, however, have decreased the availability of this fuel source. In addition to this strain on forests, community members have begun to produce charcoal in greater amounts in recent decades, with the intent of selling the charcoal at local markets as a source of additional income. An increasing preference for

charcoal as a primary cooking fuel is prevalent, however unavailable to most villagers as it is too expensive.

Biochar pyrolysis technology presents an opportunity to address the gaps present in agricultural production and fuel use in rural Haiti. Biochar use as an agricultural soil amendment is shown to improve soil characteristics and crop yields (Sohi et al., 2009), which could play a factor in reversing declining agricultural yields. When the advantages of biochar use during informal discussions were explained, villagers showed interest in adopting the technology. Additionally, biochar's use as green charcoal could play a role in reducing consumption of local tree stands through the provision of a renewable fuel source. As biochar is essentially a form of charcoal, it would mesh well with the increasing preference for charcoal as the primary cooking fuel.

Within the context of technological adoption and its influence on the livelihoods assets of the SL framework, the La Coupe region and biochar both present several potential advantages. As noted by Adato and Meinzen-Dick, past attempts and agriculturally-based technology adoption have encountered asset-related barriers. Resource-poor Kenyan farmers chose not to adopt soil-improving technologies with similar results to biochar due to a lack of natural and human capital. More specifically, land-ownership constraints allowed only the very wealthiest people who owned land to adopt the technology. The Haitian land tenure system, however, has distributed land ownership across society much more evenly than most developing countries. As indicated by interviews, 75% of respondents in Cinquantin and 80% of respondents in La Boule own land, indicating that this form of natural capital is not a significant natural asset constraint. That natural capital in the form of land ownership does not constrain Haitian farmers to the degree it does elsewhere suggests soil-improving technologies

such as biochar have the potential to be adopted more readily in the context of Cinquantin and La Boule.

The relative equity in land distribution is an important aspect of Haitian social structure that potentially may increase the likelihood of a technological innovation related to use of the land. Social equity is an important factor influencing success of technology diffusion (Rogers, 2003). Diffusion theory suggests that the high rate of land ownership in the La Coupe region is conducive to the adoption of agricultural innovations such as biochar pyrolysis.

While adoption of biochar pyrolysis may not be significantly hindered by inequality in terms of land ownership and distribution, Bordenave's (1976) question about whether or not the innovation contributes to inequality is uncertain. The benefits of biochar will rest solely with those who have agricultural land upon which they can harvest leftover biomass, thus excluding 25% of Cinquantin's population and 20% of La Boule's. Due to close family ties within the villages, it is likely that land-owning households will share some potential benefits derived from biochar with non-land owning households. Further research in La Coupe is required to determine this conclusively.

As discussed in Chapter 2, Mexican farmers chose not to adopt a new variety of maize because of increased costs due to fertilizer requirements. In this example the primary constraint is financial capital in the form of available money to be spent on fertilizer. Biochar production, however, predominantly draws upon a resource farmers already have in abundance, biomass from crop leftovers, and as proposed below, requires little financial burden for production. If the cost of investment in production is ensured to be below the threshold of financial constraint, unlike the example of the Mexican farmers, the likelihood of biochar adoption will most likely increase.

The identification of potential early adopters of biochar pyrolysis technology is an important step in improving the technology's chances of widespread adoption. Based on Rogers' (2003) theory of diffusion, possible attributes of villagers that will be more likely to adopt a new technology earlier follow. Wealthier villagers, as measured by ownership of large plots of land, multiple technologies, and many livestock, are considered to be potential early adopters (Rogers, 2003). In addition, those who have shown evidence of innovation and technology adoption in the past are considered potential early adopters (Rogers, 2003).

Based on Diffusion of Innovations theory mentioned in Chapter 2, early adopters generally have sufficient wealth to enable a risk-taking venture, have access to ideas beyond those accessible to the rest of the community, and have shown evidence of adopting a technology or innovation in the past that perhaps others within a community have not yet adopted (Rogers, 2003). Based on the correlation analysis of variables collected during individual interviews (see Table 8), likely early adopters can be identified. Potential early adopters include households that own flashlights, own horses, grow rice, and use irrigation. Perceptions towards community ownership may indicate which households are more likely to adopt a community-based pyrolyzer versus those that are more likely to adopt a household-sized personal pyrolyzer.

Households that own flashlights – a form of technological adoption – correlate fairly strongly with those that own cows, a type of livestock that reflects a higher level of wealth in rural Haiti. Flashlight ownership correlates closely with radio ownership, which is another form of past technological adoption. Households that own flashlights also correlate fairly strongly with those that have irrigation in their fields. Irrigation may be considered a representation of a past instance of both technological adoption and investment in physical capital as part of the SL framework's asset pentagon.

Additionally, it shows a willingness and/or ability on the part of villagers to invest in agricultural improvements. Similarly, households that own flashlights correlate with those that use any form of fertilizer, including manure. Again, this represents an example of adoption of a new technology and methodology, as well as an example of interest in improving agricultural practices.

Based on these results, households that own flashlights are considered to be potential early adopters of an agriculturally-based technology, such as biochar pyrolysis. They tend to be wealthier, as shown by cattle ownership and technology ownership, therefore have the ability to invest in and take risks with new technologies. Furthermore, these households have shown past instances of interest and investment in agricultural improvements and agriculturally based technology adoption. Based on Rogers (2003) definition of early adopters, evidence of past technology adoption, particularly in the agricultural sector, suggests these households will be more likely to adopt a new agriculturally-based technology like biochar pyrolysis.

Households that own horses may be considered relatively wealthier. Horses act as wealth indicator due to the cost to purchase and maintain the health of a horse, and that only 20% of interview participants report owning a horse. Horse ownership correlates weakly with cell phone ownership, evidence of investment in a new technology. Additionally, households that own horses correlate weakly with ownership and use of non-traditional farming tools. The majority of households use a pick and a hoe as their only farming tools. Less than 5% of households reported using any additional, non-traditional farming tools. Adoption and use of non-traditional farming tools shows a past instance of both technology adoption and an interest in investing in agriculturally-based technology. Irrigation correlates with households that own horses as well, additional evidence of investment in technology and an interest in improved agriculture.

These results suggest households that report owning horses are potential early adopters of an agriculturally-based technology such as biochar pyrolysis. Horse ownership indicates a relative level of wealth that would allow for investment in a risk, such as the adoption of a new technology. Horse ownership correlates with cell phone ownership and non-traditional farming tool ownership, both of which indicate a predilection for technology adoption, especially adoption that is against the norm in the case of the non-traditional tools. Early adopters of a technology are generally risk takers who deviate from social norms (Rogers 2003), suggesting that horse-owning households are likely early adopters. Additionally, as with households that own flashlights correlating with irrigation, households that own horses correlating with irrigation suggests both evidence of past technology adoption as well as an interest in improving agricultural methodologies. These characteristics indicate villagers potentially more likely to adopt biochar pyrolysis technology.

In addition to the correlation between households that use non-traditional farming tools and horse ownership, a fairly strong correlation exists between non-traditional tools and fertilizer use. Both indicate an interest in adopting agricultural technologies and behavior against the norm of the two villages, suggesting that these are likely early adopters of biochar pyrolysis.

Households that report growing rice are shown to correlate with radio ownership, and strongly correlate with flashlight ownership. These correlations suggest that these households are more likely to have invested in technologies in the past, can be considered to more likely invest in technology in the future, and therefore are likely early adopters of new technologies.

Households that grow sugarcane correlate with those that use charcoal, indicating that these households are potential early adopters of the green charcoal aspect of

pyrolysis, whereby the charred biomass resulting from pyrolysis is used as a fuel rather than a soil amendment. Dried sugarcane stalks, known as *bagasse*, have been shown to be an efficient and effective source of biomass for pyrolysis (Lehmann & Joseph, 2005). As charcoal use is somewhat uncommon (at 30% in both villages), those households that grow sugarcane and already use charcoal may represent an opportunity to disseminate and examine the potential of pyrolysis technology as a method by which to produce cooking fuel.

Households that own any form of technology, including radios, flashlights, and cell phones, correlate strongly with those that report having agricultural leftovers after harvesting their crops. As shown above, households possessing technologies are already considered likely early adopters of biochar technology. This additional correlation suggests that these households are more likely to have sufficient biomass inputs to facilitate continued production of biochar, increasing the likelihood of adoption and continued use of biochar pyrolysis.

Reports of fertilizer use and charcoal use correlate negatively, suggesting a potential opportunity or barrier for pyrolysis use. A potential barrier to pyrolysis adoption and use could be a conflict inherent in the use of the charred biomass produced: will families use it as a soil amendment or a fuel source? How is this decision prioritized and made? As shown by this negative correlation, families who use fertilizer and are potentially more likely to adopt a similar technology such as biochar use in soil, may be less likely to use charcoal and potentially use resulting charred biomass from pyrolysis as such, and vice versa. This dichotomy could help facilitate the use of pyrolysis technology at the household level, as adoption the technology will be more likely if it has multiple uses and allows users to choose the most pertinent application (Geroski, 2000).

It may also hinder adoption, as people who are able to use the technology for two tasks as opposed to one will derive more benefit from a pyrolyzer.

Identification of community ownership, such as shared water or labor, correlates negatively with both irrigation and ownership of non-traditional farming tools. As the water source used for irrigation, the Mahotier stream, is regulated and for the most part controlled by the Houngan, or Vodou priest, it comes as no surprise that those who irrigate their fields using this water source are not likely to identify with community ownership. Additionally, households that own non-traditional tools potentially go against community opinions as shown by the adoption of uncommon technologies, and therefore may be less likely to identify with community ownership as well. This trait may present an opportunity to introduce varied pyrolysis technology models, which may increase the likelihood of overall adoption (Geroski, 2000). Specifically, households with non-traditional tools and irrigation may be more likely to adopt individually owned pyrolyzers, as they may be less community oriented, while other households may be more likely to adopt a larger pyrolyzer that's use is shared by the community.

Upon selection and engagement of early adopters as identified by use of irrigation, the "epidemic diffusion" model suggests that an important next step will be dissemination of information about biochar technology (Geroski, 2000). A significant reason for a lack of biochar's presence in rural Haiti is a lack of knowledge about its existence by farmers. In the rural setting of La Coupe, this can be accomplished through direct engagement of villagers by an external organization, such as a non-governmental organization, through educational sessions, workshops, and demonstrations that incorporate local knowledge and practices. According to Rogers' attributes of technologies, an effective method to spread knowledge about biochar will be its observability. Crop yield increases should be quite visible (Sohi et al., 2009), allowing

for the neighbors and friends of early adopters to witness the benefits derived from biochar's use.

Education and dissemination about biochar pyrolysis technology should be coupled with several options regarding the technology. As noted by Geroski, choice about various technologies is an important factor to increase likelihood of adoption (2000), similar to Rogers' notion of triability, or ability to adjust the technology to one's specific needs. In light of various technologies available – from small-scale single-barrel batch pyrolyzers sufficient for one household to large-scale continuous pyrolyzers sufficient for a village – villagers should be present with all options and allowed to select the technology that best fits their specific budget and needs.

Both La Boule and Cinquantin have potential opportunities for initial introduction and adoption of biochar pyrolysis technology. Because of La Boule's location at the end of a road, it is more accessible than Cinquantin and thus has more access to communication channels and transportation to cities and markets. This opens La Boule up to diverse ideas more commonly than Cinquantin, and increases the likelihood of adoption of newer ideas (Rogers, 2003). In addition, there are several instances of personally owned technologies that are used (if only indirectly) by many people. These include the forge, the propane oven, and the sewing machine, all instances of previous technology adoption by individuals with the intent of providing a service or product at a fee for an increased personal income. A potential barrier to adoption in La Boule is a less-dominant agricultural sector as part of its economy.

Cinquantin has the grain mill that follows this ownership-use model, representing an advantage in terms of past experience with similar technology. These instances indicate that the adoption of another such privately-owned technology is potentially likely based on previous familiarity with the model (Rogers, 2003). As use of the mill

appears to decrease with distance, proximity to Cinquantin may be indicative of likelier adoption of a similar technology. A potential barrier to adoption of technology in Cinquantin is a less-active communication channel.

Ownership of a private technology used by others at a nominal cost, using the mill in Cinquantin as an example, provides a viable potential model of use for biochar pyrolysis technology. Specifically, the mill and biochar pyrolysis technology are potentially similar in several respects. Both can be owned by a single person who charges others a fee per use. This use involves individuals bringing a product to the technology to alter the product in a way that adds value. For example, the mill processes grains, and the pyrolyzer chars biomass. Depending on the mill and pyrolyzer, both processes take approximately 30-45 minutes for one “batch” equivalent to approximately 20-30 pounds. Due to this similarity, the process is a potentially familiar one to those who regularly use Cinquantin’s mill. Through singular ownership, access to the pyrolyzer is opened to the rest of the villagers who might not otherwise be able to afford the technology.

As women are primary users of the mill, a similar use model might provide a potential role for women with respect to the use of a pyrolyzer. As previously noted, women already participate much more in the charcoal economy and its use, and they are familiar with the model of regularly transporting grains to use the mill. As noted in Chapter 2, engaging women with economic and social resources not only provides an effective method of addressing needs as new resources are invested back into the community more significantly than new resources provided to men, but also women actually do this more efficiently in many cases (Kristof & WuDunn, 2009; Tinker, 1990). This model may provide increased positive externalities from any augmented income derived from improved crop yields in terms of further education and healthcare for

families and children (Tinker, 1990). As women are familiar with such a model, are they potentially are more likely early adopters of a community-used pyrolyzer model, and engaging them has potential to result in positive externalities for the community as a whole. These externalities may be increased income from sale of biochar or crops, more confidence from a new key community role, or increased livelihood security as a result of increased incomes.

Strategic Action Plan

A future plan of action for the introduction of biochar pyrolysis technology a biochar use as a soil amendment in the La Coupe region follows. Households with irrigation and radios could be initially targeted as potential early adopters of pyrolysis technology, while women could be engaged specifically as potential facilitators of biochar production with a community-based pyrolyzer. Further education through demonstrations and workshops should be conducted to disseminate information about biochar production and use. Villagers should be presented with options regarding biochar technology, including smaller individual-household-sized pyrolyzers and larger community-scale pyrolyzers. Within La Boule and Cinquantin, various opportunities and barriers exist for adoption. Both communities should be engaged in information dissemination regarding biochar pyrolysis technology as outlined above. Upon testing of biochar in a demonstration plot and dissemination of biochar technology, further research is recommended to analyze the success or failure of biochar's effect on soils and its adoption in these two villages. This action plan is coupled with a Gantt chart (Appendix D), which contains each primary action and an associated timeline.

The following plan of action is designed around an October to November-planting season as shown in Figure 6. Actual dates will vary most likely, as rains vary

locally and planting should coincide with the appropriate local farming schedule in any given location. Individual actions are numbered 1-13, and correspond to the Gantt chart and timeline in Appendix D.

1. Build Demonstration Plot

A one-acre demonstration plot is to be constructed in Cinquantin over a one-month period. The location will be a plot of land that local community members have provided on otherwise unused land. This plot should be divided into two sections: one half with biochar mixed into the soil, another half used for a control group with no biochar added. Construction will involve delineating the two sections of the plot, removing rocks and other natural vegetation, and loosening soil to prepare for planting. Village farmers should be engaged to apply local knowledge to the plot preparation. The demonstration plot will serve two purposes: one, to measure the effectiveness of biochar in a local context; and two, as an education tool to show local farmers how biochar is used and what the potential results are. This will break down potential adoption barriers due to lack of biochar knowledge, increasing the likelihood of future adoption based on the epidemic diffusion model (Geroski, 2000).

2. Identify Early Adopters

Upon completion of the demonstration plot, potential early adopters of biochar pyrolyzers should be identified over a three-week period of selection and engagement. Early adopters are considered households that have sufficient wealth to enable risk-taking ventures, have access to new ideas, and have shown past evidence of adopting innovations that are otherwise uncommon in a community (Rogers, 2003). As indicated before, these should be households with irrigation and radios, both instances of past

innovation, as well as those with more livestock such as horses, evidence of more wealth, taking special care to include women in the education process so they may be engaged during the introduction of the community-based pyrolyzer. As early adopters are potentially more likely than the rest of the community to adopt a new technology, these households will serve as a gateway for biochar pyrolysis adoption in the villages and a stepping stone to more widespread adoption within the community (Rogers, 2003).

3. Initial Production of Biochar

Initial production of biochar should then take place. For a half-acre lot, an initial application of approximately .25 tonnes, or ~1,000 pounds, of biochar is recommended based on results shown by Sohi et al. (2009). The production of this amount of biochar will require approximately 3,000 pounds of biomass, and roughly 30 batches using the double-barrel pyrolyzer already in place in Cinquantin. At two to three hours per batch, this will take between 60 and 90 hours, which can be spread over a two-week period. Biomass for this initial production can be collected in increments over the two-week period, as only 200 to 250 pounds will be required per day. According to group discussions, women in children in Cinquantin are willing to help with this initial gathering of biomass and should be engaged for this purpose. Biomass should be plentiful at this time, as these actions should coincide with the end of the summer harvest season, which sees the production of millet. Millet is shown to be an efficient source of biomass for biochar production (Sohi et al. 2009).

4. Workshops with Early Adopters

It is recommended that workshops and demonstrations be held concurrently with the production and application of biochar. Early adopters will be shown the process of

biomass preparation, biochar production and pyrolyzer use, as well as soil preparation with biochar (as follows in action 5). These are to be conducted initially by the organization implementing this action plan as part of their project operational budget. As local farmers learn about the process of biochar use, local volunteers will be identified and trained to carry out future workshops to educate other communities in the preparation and use of biochar. Engagement and empowerment of local villagers in the implementation of this project will result participatory control and education, enabling community members and increasing the likelihood of project success (Davis & Garvey, 1993). Additionally, dissemination of knowledge will remove technology awareness barriers to adoption, potentially increasing the likelihood of widespread adoption of biochar pyrolysis (Geroski, 2000).

5. Prepare Plot With Biochar

Following the production of biochar, roughly two weeks should be spent applying the recently produced biochar to the soil in the biochar half of the demonstration plot. The application process of biochar will be labor-intensive, as the tools will be limited to locally available picks and hoes. The ~1,000 pounds of biochar will be transported to the demonstration plot from the pyrolyzers – an approximately 400 meter walk. The biochar will be in a fine, powdered form and applying it will consist of spreading the biochar over the soil while using the picks and hoes to blend it with the soil to a depth of approximately one half to one meter so that an overall amount of .5 tonnes per hectare is reached. This level of biochar production is recommended for increased yields, and will also allow for comparison of results with other studies (Sohi et al., 2009).

6. Plant Maize

After the soil is prepared, maize should be planted evenly in both the control half and biochar-treated half of the demonstration plot using local techniques to ensure locals can replicate the process in the future. Villagers identified as early adopters should be encouraged to participate actively and to share their knowledge of local planting practices. Continued engagement and empowerment of locals in the implementation of each stage of the project is an important factor in increasing the long-term success of project (Davis & Garvey, 1993). This is to be done during the month of October, coinciding with the local planting season. Much of the labor will need to be done by the implementing organization, as locals will be busy planting their own crops.

7. Maize Growth

Maize should be allowed to grow as is standard locally. While varying from region to region, the Haitian fall growing season is approximately from October through February, although the initial harvesting is done as early as December (Figure 6). Crops will need to be weeded and maintained as per local traditional practices. The continued engagement of local farmers eliciting the sharing of local knowledge is important throughout the growing process. Maize growth should last from approximately mid-October to mid-December.

8. Harvest Maize

Once the maize has grown and adequately matured after approximately two months (actual times will most likely vary), the maize should be harvested. As with planting, locals should be engaged and empowered during the harvest process to bolster potential project success (Davis & Garvey, 1993). Traditional harvest techniques should

be used to ensure methods are replicable in the future. The implementing organization will need to do much of the labor, as local farmers will be occupied with their own harvest. Special care should be taken to keep maize grown in biochar-treated soil separate from maize grown in un-treated soil. The process of harvesting the maize should last approximately one month, during December, and should be done concurrently with step nine.

9. Weigh and Compare Results

As the maize is harvested and transported to storage areas, it should be weighed to determine the total weight of the maize grown in the control plot and the maize grown in the biochar plot. This will allow for a comparison in total growth between the control plot and the biochar plot, and serve as a metric upon which to base future estimates for biochar effectiveness within the context of central Haiti. Villagers identified as early adopters should be encouraged to participate so any benefits derived from biochar use are immediately recognizable.

10. Evaluate Effectiveness of Biochar

Weighing the maize harvested from the two halves of the demonstration plot will allow for an assessment of biochar's effectiveness with respect to local crop yields and a benchmark for future expansion of biochar use as a soil amendment in the La Coupe region of Haiti. Additionally, as weight of a harvest is a common metric for measuring the effectiveness of biochar, this will allow for a comparison between the results of this project and the results of other biochar application projects (Sohi et al., 2009). A comparison in resulting yields will provide a metric for success of this and other biochar projects.

11. Distribution of Individual Pyrolyzers

After the initial demonstration plot test, simple batch pyrolyzers, such as the TLUD units described in Chapter 2, should be distributed to early adopter households in La Boule for initial use while continuing educational workshops to familiarize early adopters with the use of the pyrolyzer technology. Initial construction of the units must be done by the implementing organization, requiring approximately two and a half 55-gallon drums per unit at a cost of about US\$10.00 per drum in Port-au-Prince. A pricing scheme for distribution must be established by the organization. Following a small-scale loan model is recommended to increase initial affordability for early adopters.

12. Preparation of Community-Scale Pyrolyzer

Villagers in Cinquantin identified as early adopters should be introduced to the use and management of the continuous community-scale pyrolyzer – the BEK unit described in Chapter 2. During operation, this pyrolyzer should be located centrally so it is easily accessible to all villagers, preferably near the existing mill. A caretaker who will maintain the community pyrolyzer will be identified and educated about the BEK's use and maintenance by the implementing organization. Initial use of this pyrolyzer should be priced equivalent to one turn on the mill in Cinquantin. A portion of each payment should go to the maintenance and upkeep of the pyrolyzer, and the rest should go to the caretaker. As the caretaker is paid per use, an incentive will be in place to prevent the pyrolyzer from falling into disrepair.

13. Continued Workshops and Engagement

After distribution of individual household pyrolyzer units and introduction of the community-scale pyrolyzer, the implementing organization should maintain a presence in the villages to provide additional support in the initial production and application of biochar. This will also allow the organization to facilitate the adoption of any pyrolyzers by other villagers who may show interest after the initial introduction. The following major planting season is not until the arrival of the rainy season, or roughly mid-April, allowing pyrolyzer adopters several months for biochar production and application to soils.

Upon final completion of this initial phase of the project, the following accomplishments will have been completed: testing and demonstration of biochar's effectiveness in the study villages, distribution of pyrolyzers and biochar production capability to early adopters, and educational workshops on production and use of biochar. This whole phase is estimated to take six to seven months, from the preparation in the summer, through the fall planting season, and into the winter harvest season.

Project success will be determined by several metrics (shown in Table 9): pyrolyzer use by early adopters one year from initial introduction; crop yields of early adopters after the first harvest using biochar (actual metric of percentage increase to be determined based on demonstration plot test); and adoption of pyrolyzer use or biochar use by non-early adopters in villages. If a majority of early adopters continue to use pyrolyzers and biochar within one year of introduction, the project will have been successful in this regard, however if a majority have discontinued use this metric will have not be considered successful. Data from the biochar demonstration plot should be used as a benchmark to refine the metric for percentage crop yield increase. This

percentage yield increase metric should be the average increase seen in the demonstration plot. Finally, pyrolyzer adoption and biochar use by non-early adopters is a key metric for success, as this will indicate diffusion of the technology in the study villages.

This action plan is intended for biochar use as a soil amendment and not in the “green charcoal” form as a fuel. While there is a need for new, reliable fuel sources for cooking in both study villages, green charcoal’s adoption not only requires pyrolyzer

Table 9. Project success metrics.

Metric	Success	Failure
Early adopter pyrolyzer and biochar use within one year	>50% of early adopters are using pyrolyzers and biochar	>50% of early adopters have discontinued pyrolyzer and biochar use
Crop yields after first harvest with biochar used as soil amendment	Increase in crop yield biomass	No increase or decrease in crop yield
Pyrolyzer or biochar use by non-early adopters	Within one year of introduction non-early adopters have begun use	No use by non-early adopters within one year

technology, but also calls for presses to compact the powdered biochar into briquettes. As it may be more difficult to introduce two innovative technologies at a time than one, this study recommends preliminary introduction of pyrolyzer technology and biochar’s use as a soil amendment primarily. Once pyrolyzers are more widely adopted, then another action-oriented plan should be developed to introduce briquette presses and the use of green charcoal.

After the initial phase of project development, the following is suggested as a potential routine for biochar production and use. The assumption of pyrolyzer ownership or access to a community pyrolyzer is made in this routine. After harvesting crops, households and their neighbors share the task of gathering biomass and transporting it to a location where it may be dried. During the wet season, this may be a small shed or shelter that protects the biomass from the elements so that it may be sufficiently dry for

pyrolysis. The gathering and drying process may be done in batches of 100 pounds of biomass (after drying), which is equivalent to one batch of biochar in a double-barrel pyrolyzer. After biochar is sufficiently dry (less than 10% moisture by weight – actual drying time will vary based on season), the biomass is placed in either the household’s pyrolyzer unit, or taken to the community pyrolyzer, where it is to be converted into biochar. This process will take approximately two to three hours. If using the community pyrolyzer, the biomass will be weighed and the villager charged a nominal fee for the use of the pyrolyzer based on the weight of the biomass to be pyrolyzed. After the biochar has been produced, it will be transported back to the field in 20-30 pound batches using ubiquitous plastic sacks currently used for transporting wood-based charcoal. At the farmer’s field, the biochar will be mixed into the soil 20-30 pound batch at a time. This process may be done over several months or several years, until approximately 0.5 tonnes of biochar per hectare has been achieved.

Chapter 6

CONCLUSIONS

The objectives of this thesis, as stated in Chapter 1, were to: 1) identify agricultural and fuel use-related needs and gaps in rural Haitian communities; 2) determine the appropriateness of biochar pyrolyzer technology in the study villages; and 3) develop an action-oriented plan for use by development organizations, communities, and governmental institutions to increase the likelihood of adoption. This chapter will summarize the findings for each of these objectives and suggest future research.

Objective #1: identify agricultural and fuel use-related needs and gaps in rural Haitian communities. In light of declining agricultural productivity across Haiti, contributing to pervasive poverty and malnutrition, coupled with declining firewood availability, biochar pyrolysis technology may present a viable intervention by which to address these needs and gaps. Interview and group discussion data corroborate national data, indicating growing needs for food security and a way to address declining crop yields, as well as declining fuelwood availability.

Objective #2: determine the appropriateness of biochar pyrolyzer technology. In the context of the villages of Cinquantin and La Boule, biochar is determined to be a potentially viable agricultural and fuel-based technological intervention. Pyrolyzer technology and use of biochar as a soil amendment has the potential to curb falling crop yields in the study villages. Both villages present opportunities and barriers to biochar pyrolysis adoption. La Boule's population has shown a predilection for investing in innovative technologies and there is a greater accessibility to communication channels and transportation. Cinquantin's familiarity with a grain mill makes adoption of a similar technology likely.

Objective #3: develop an action-oriented plan for use by development organizations, communities, and governmental institutions to increase the likelihood of adoption. The following plan of action is recommended to increase the possibility of successful biochar adoption. Likely early adopters of biochar pyrolysis technology should be engaged first, and include households that use irrigation, as they have been shown to be more likely to invest in technology. Upon the identification of likely early adopters, education about pyrolysis technology should be used to disseminate information about and adoption of biochar use. Villagers should be provided with options regarding technologies so they may select one more pertinent to their needs and capabilities, such as individual-household-scale pyrolyzers and community-scale pyrolyzers. Both Haitian villages should be exposed to biochar technology using a demonstration plot. Further research is needed on the specific potential of biochar's effects on local crop yields as indicated by the proposed demonstration plot experiment with maize.

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APPENDIX A
INDIVIDUAL INTERVIEW GUIDE

Individual Interview – Final Version

Age and gender?

How many people live in your house?

Does your family own any land? If so, how much?

What crops do you grow?

Where do you get your seeds?

Do you use anything to help your crops grow? Manure? Fertilizer?

If yes, where did you learn how to use them? How long have you used them?

If no, why don't you?

Where does your water used for agriculture come from? How do you access it?

What are the months with the last amount of rain? The most?

What tools do you use to harvest your crops?

Do you own any draft animals? If yes, what kind and how many?

On average, how much does your family spend for food per day?

\$0-50, \$50-100, \$100-150, \$150+

Who in your family does the work of farming? How does this change from season to season?

Is the work of farming every shared between families (neighbors, friends, etc)?

Do you ever sell any of your crops at the market?

If yes, how much do you make in a season?

What are the biggest hardships you face with farming?

After you harvest your crops for food, what agricultural leftovers remain?

What is done with these leftovers?

Which crops leave the most leftovers? The least?

.....

What kinds of fuel does your family use?

What do you use fuel for?

Given a choice, what kind of fuel would you prefer to use? Why?

What portion of your fuel do you collect? Who does this?

What portion of your fuel do you purchase? How much do you spend?

Do you ever make charcoal? Do you sell it?

On average, how much fuel do you use for cooking in one day?

Have you noticed any change in fuel use during your lifetime?

.....

What technologies do you have in your home?

How did you come to own this technology?

(If broken) Why haven't you fixed it?

What are the costs involved with owning the technology?

Is anything owned by the community – shared among people?

Who owns the water? How is it accessed?

Are there any technologies shared by people (like a mill)?

How often does your family use it?

Do you participate in *gagé* or any similar activities?

Since your youth, have you noticed a change in the amount or type of food the land is able to produce?

If so, why do you think this change has occurred?

APPENDIX B
GROUP INTERVIEW GUIDES

Focus Group – Technological Adoption Strategies

1. What technologies do you have in your home? (i.e. radio, flashlight, farming tools, mill, etc.)
2. What technologies would you like to acquire?
3. How do people access/come to own technologies? How do people find out about new technologies?
3. What are some barriers to access to technology?
4. Who is most likely to use/buy a new technology?
5. What technologies are associated with cooking?
6. What technologies are associated with farming?
7. (If you have seen biochar,) What would make using biochar a reality in your village?
8. (If you have seen biochar,) What would prevent you from using biochar?
9. Is anything owned collectively by the community? What?
10. Who owns the forests? The water?
11. Who determines how the mill is used? How is payment made? Who runs it?
12. (Willingness to pay...)

Focus Group - Agriculture

1. What crops are grown around the village?
2. Do farmers grow enough for their families?
3. What tools do people use for farming?
4. Where do farmers get water?
5. How does the amount of water available vary?
6. Do farmers use anything to help their crops grow? (i.e. fertilizer, manure)
7. Who does the work of farming?
8. Do people own draft animals?
9. After you harvest your crops, what happens to the waste (maize stalks, rice paddies, etc.)
10. Do you sell your crops? How? Where?
11. What are the prices of foods?
12. What is a weekly food expenditure?
13. What are the costs involved with farming?
14. What are the agricultural leftovers from different crops? What is done with them? How much is there?

Focus Group - Fuel

1. What kinds of fuel do you use?
2. What do you use fuel for (cooking, heating, energy, animals, alcohol, industry)?
3. Where do the different kinds of fuel come from? Purchased? Collected? How much for each?
4. How much do you spend each week on fuel? How often do you buy fuel?
5. Are you able to collect any cooking fuel near your house? How far do you go?
6. If you collect cooking fuel, what types do you prefer?
7. Who is responsible for collecting cooking fuel? For buying cooking fuel?
8. Who sells cooking fuel? How much does a bag of charcoal cost? Wood?
9. How has your fuel use changed over your lifetime?
10. How has your fuel use changed after the January 2010 earthquake?
11. What methods do you use to cook your food?
12. How many meals a day do you cook? How much fuel is used in a day?
13. Do you use different fuel types for different purposes? (e.g. charcoal for food, wood for other)
14. Who makes charcoal? Does everybody know how? How do people learn?

Time Line

Materials: Sheet paper and markers

Participants: 3-5 elder community members, both genders

Introduction:

The purpose of this exercise is to identify the key events in the community to understand past trends, events, problems, and achievements. The timeline will further identify trends and patterns in agriculture and fuel use.

Probing Questions:

1. What were the main events in the village?
2. When did this community settle here?
3. Who were the founders of this community?
4. What was the first important event that you can remember in the community?
5. Have there been migrations, epidemics, famines, floods, droughts, or other natural disasters?
6. What are some of the best things the community has done?
7. What were some of the happiest times?
8. How has resource use changed?
9. Do you have any old photos of your village and the surrounding area?
10. How has tree cover changed?

APPENDIX C
INFORMATIONAL LETTERS

INFORMATION LETTER - Focus Group
**Analysis of Livelihoods and Technological Adoption Strategies in La
Coupe, Haiti**

January 2011

Dear _____:

I am a graduate student under the direction of Professor Rimjhim Aggarwal in the School of Sustainability at Arizona State University. I am conducting a research study to understand local livelihood patterns and perceptions towards adoption of biochar-based technology.

I am inviting your participation, which will involve participation in a focus group discussing local resource use, daily activities, and community trends. The duration of the focus groups will be 1 to 2 hours. You have the right not to answer any question, and to stop participation at any time.

Your participation in this study is voluntary. If you choose not to participate or to withdraw from the study at any time, there will be no penalty. You must be 18 or older to participate in the study.

Although there is no direct benefit to you, possible benefits of your participation are an improved understanding of livelihoods and resource use in your village and the development of a relationship between the community and the researcher, who may begin other projects. There are no foreseeable risks or discomforts to your participation.

Your responses will be anonymous. As this is a focus group, complete confidentiality cannot be maintained. The results of this study may be used in reports, presentations, or publications but your name will not be used. Results will only be shared in the aggregate form.

I would like to audiotape this focus group. You will not be recorded, unless you give permission. If you give permission to be taped, you have the right to ask for the recording to be stopped. The audio recordings will be stored on an external hard drive in a locker in the School of Sustainability to which only the researcher has a key. The audio recordings will be deleted after transcription and translation, which is expected to be by March 15, 2011.

If you have any questions concerning the research study, please contact the research team at:

Dr. Rimjhim Aggarwal – 480-965-6680, rimjhim.aggarwal@asu.edu

Ryan Delaney – 206-669-8163, mrdelane@asu.edu

If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at (480) 965-6788.

The research team can be contacted through cell phone locally at: 3603-4836

By signing below you are agreeing to participate to in the study.

Signature

Date

By signing below, you are agreeing to be taped.

Signature

Date

INFORMATION LETTER - Interview
**Analysis of Livelihoods and Technological Adoption Strategies in La
Coupe, Haiti**

January 2011

Dear _____:

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I am inviting your participation, which will involve participation in an interview regarding local resource use, daily activities, and community activities. The duration of an interview will be 45 minutes. You have the right not to answer any question, and to stop the interview at any time.

Your participation in this study is voluntary. If you choose not to participate or to withdraw from the study at any time, there will be no penalty. You must be 18 or older to participate in the study.

Although there is no direct benefit to you, possible benefits of your participation are an improved understanding of livelihoods and resource use in your village and the development of a relationship between the community and the researcher, who may begin other projects. There are no foreseeable risks or discomforts to your participation.

All information obtained in this study is strictly anonymous. The results of this research study may be used in reports, presentations, and publications, but the researchers will not identify you.

I would like to audiotape this interview. The interview will not be recorded without your permission. Please let me know if you do not want the interview to be taped; you also can change your mind after the interview starts, just let me know. The audio recordings will be stored on an external hard drive in a locker in the School of Sustainability to which only the researcher has a key. The audio recordings will be deleted after transcription and translation, which is expected to be by March 15, 2011.

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The research team can be contacted through cell phone locally at: 3603-4836

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Please let me know if you wish to be taped.

APPENDIX D
PROJECT GANTT CHART

