

Vetiver Briquette

FEASIBILITY REPORT



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Executive Summary

As part of the Côte Sud Initiative, the United Nations Environment Programme (UNEP) commissioned Carbon Roots International (CRI), a green charcoal enterprise in Haiti, to analyze the feasibility of implementing a vetiver charcoal initiative in the South Department. The present analysis assesses the technical and commercial feasibility of implementing an enterprise designed to use vetiver waste as the primary feedstock for green charcoal production. The report analyses the industry landscape in Les Cayes and the greater South Department, availability of vetiver biomass, cost and timeline of various applicable business models, and technical efficacy of vetiver waste as a feedstock for charcoal energy.

As previous cooking fuel and cook stove initiatives have shown, a successful green charcoal venture needs to offer a product that compares favorably to wood charcoal in both price and quality. To have a meaningful impact and sustain itself financially, the venture should also be able to scale in a cost-effective manner. CRI's operations in Cap-Haitien set the standard for what a sustainable charcoal initiative can and should accomplish. Based on this experience, it is expected that a vetiver charcoal initiative should aspire to produce a minimum of 15 metric tons of charcoal a day. Furthermore, a successful green charcoal initiative should be able to reach profitability while selling charcoal at a price no higher than the cost of wood charcoal (currently 500 HTG per sack).

The South Department presents several obstacles to managing a successful green charcoal business at scale. These include the lack of a fully operational port and airport, as well as a lack of major retailers of industrial machinery and supplies. However, with the exception of Port-au-Prince and Cap-Haitien, these obstacles are neither unique to the region, nor are they insurmountable. Furthermore, the region's charcoal market operates in a similar fashion to other areas in Haiti and could likely support a new charcoal supplier.

Similar to the traditional charcoal market, the vetiver industry is largely informal, operating with very little oversight or transparency. Several major vetiver distillers control the market for vetiver roots, and competition among them is intense. Partially because of this, the quantity of vetiver waste produced in the region is largely unknown. Estimates indicate that the amount of post-processed roots available for charcoal production is low, due to the likelihood that distillers will soon use the majority of their processed roots for on-site energy. Similarly, sugarcane waste is in short supply in the region, as few sugarcane distilleries operate in the area. The lack of vetiver roots and sugarcane bagasse could be offset by the large quantity of vetiver leaves and corn waste produced in the region. However, the decentralized nature of vetiver leaf and corn production will mean that finding, aggregating and transporting both to a central facility for processing will be difficult and costly.

The enterprise model used to design a green charcoal initiative will also have a large impact on how successful the initiative is likely to be. This report compares three distinct vetiver charcoal business models to assess how certain aspects of each model could affect the initiative's timeline, milestones, and continued financial sustainability. In comparing a decentralized cooperative-owned model, a centralized distiller-owned model, and a centralized third party model, it appears that the cooperative model is the least likely to produce a quality vetiver briquette at scale. Furthermore, the analysis finds that a third party model is the most likely to focus on marketing and sales, a crucial aspect of increasing demand for sustainable charcoal.

To better understand the efficacy of vetiver as a feedstock for charcoal production, this report presents the findings from field trials performed by CRI at its facility in Cap-Haitien. CRI tested the performance of vetiver leaves and grass at various stages of charcoal production, from pyrolysis and briquetting to cooking. Results showed that charcoal made from vetiver roots were ineffective, due to the quantity of dirt and other sediment attached to the roots even after pyrolysis. Conversely, vetiver grass performed very well across the board, indicating that as an energy source, it would be just as effective as sugarcane bagasse.

Due to the unsuitability of vetiver root charcoal and the lack of vetiver root available in the near future, it is not recommended that a vetiver briquette initiative be implemented in the South at this time. Should a vetiver briquette initiative move forward in the future, it is recommended that vetiver leaves be considered more prominently as a source of biomass, and that a third party enterprise manage the initiative, so as to improve its likelihood of scaling as both a manufacturer and retailer of sustainable charcoal.



For this study, CRI tested the performance of vetiver leaves and grass at various stages of charcoal production

Introduction

It is estimated that over 90% of the Haitian population is reliant on biomass (primarily wood-based charcoal and firewood) for cooking fuel, signifying that Haitians likely use over 3,000 metric tons of charcoal a day, or 1.09 million tons each year.¹ This reliance on wood charcoal has reduced Haiti's forests to 1-3% of original stands, wreaking havoc on Haiti's wildlife and soil fertility while also reducing the supply of cooking fuel.²

Finding a viable alternative to wood charcoal should, therefore, be a major priority. Based on its success, UNEP recognized the potential of using vetiver waste as an energy source for sustainable charcoal in the South Department, and commissioned CRI to assess the feasibility of launching a green charcoal enterprise in the region.

This study evaluates the technical and commercial feasibility of implementing a vetiver briquette initiative in the South. To do so, the report first defines a successful green charcoal venture in Part I, outlining how it should function and what it should be expected to accomplish. Understanding what the vetiver briquette project should achieve, the report then addresses the major factors that are likely to affect the venture's success. Part II assesses the Southern region's infrastructure and key resources, as well as the two local markets most pertinent to a green charcoal venture, the charcoal market, and the vetiver industry. Part III addresses feedstock availability, or the quantity of root and leaf biomass available for charcoal production per annum. The report also assesses the availability of a variety of other agricultural by-products that could be used to augment vetiver, such as corn, sugar cane, and cassava.

After assessing feedstock availability, the report compares three distinct business models to identify what business structure and operational model best supports a vetiver briquette venture in reaching scale and having a lasting impact. The three models are 1) Distiller-Owned, 2) Cooperative-Owned, and 3) Third Party-Owned. In this section, the costs and timelines required to meet major milestones are addressed by evaluating key business variables, including input costs and revenue.

Finally, the technical feasibility of transforming vetiver waste (both distilled roots and raw leaves) into charcoal briquettes is evaluated by testing vetiver waste for charcoal production. The report presents the methodology and findings field tests performed at CRI's charcoal facility in Cap-Haitien. Based on the findings of these trials and the analysis above, the report provides a recommendation on whether or not a vetiver briquette initiative is feasible and what approach is recommended for implementing such a project.

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- 1 Carbon Roots International market analysis: If Haiti's population is 10,500,000 (*Trading Economics*); 90% (charcoal users) equal 9,450,000. Households of approximately 6 members use approximately 2 kg of charcoal a day. Thus 1,575,000 households use a total of 3,150,000 kg of charcoal a day, or 3,150 metric tons.
 - 2 McClintock, Nathan. (2003) "Agroforestry and Sustainable Resource Conservation in Haiti: A Case Study." North Carolina State University.

PART I

Building a “Green” Charcoal Enterprise

Defining Success

Haitians likely consume over a million tons of charcoal each year and Haiti’s charcoal production could be responsible for cutting up to 12 million trees annually.¹ At this rate, Haiti is likely to lose, at the minimum, more than 700 hectares of forests per year annum.²

Providing Haitians with a sustainable and viable alternative to wood charcoal is crucial. However, very few organizations have succeeded in producing and distributing viable charcoal alternatives in Haiti.³ This is due to the preference of some development organizations and funders for charcoal alternatives (e.g. charcoal made from corn husks or sugarcane bagasse) and Haitians’ preference for an affordable and familiar product (i.e. charcoal made from wood). Furthermore, manufacturing and distributing new cooking technologies is often expensive. Imported goods and labor, continuous research and development, as well as inefficient business models contribute to a high price tag per unit. Although demand for cooking fuel is relatively inelastic, Haitians do not seem willing to pay for new or improved cooking technologies, especially when they require behavioral change.⁴

Similar to other clean cooking fuels, “green charcoal” briquettes, made from agricultural waste products, directly combat deforestation. Unlike other novel cooking technologies, they are attractive to Haitian consumers because they are both cheap and familiar in functionality. CRI’s pilot program in Cap-Haitien has shown that green charcoal can be manufactured locally and sold to Haitian consumers at a price comparable to wood charcoal. Furthermore, the growing demand for CRI’s product, “Chabon Boul,” has proven that a green charcoal enterprise can be financially sustainable.⁵

For green charcoal to have a meaningful impact on deforestation, scale and urgency is key. Replacing only 5% of the wood charcoal consumed in Haiti would require 150 metric tons of green charcoal a day.⁶ By operating as a for-profit enterprise with acute focus on quality, efficiency and costs,

1 Erickson analysis based on Malimbwi et. al. 19% “tree-to-charcoal” yield in Tanzania. Malimbwi, Rogers & Zahabu, Eliakimu. (2008). “Woodland and the charcoal trade: the case of Dar es Salaam City.” Sokoine University of Agriculture.

2 Butler, Rhett. (2006). “Haiti.” Mongabay.

3 Confino, Jo & Paddison, Laura. (2014). “Cookstove designs are failing the poorest communities.” The Guardian. <http://www.theguardian.com/sustainable-business/cookstoves-design-poor-communities-refugees-unhcr-ikea>.

4 Sagbo, Nicaise. (2014). “Economic Analysis and Willingness to Pay for Alternative Charcoal and Clean Cook Stoves in Haiti.” University of Kentucky.

5 Based on CRI sales data and financial projections. CRI is currently generating revenue from charcoal sales and expects to be profitable by end of 2016.

6 CRI analysis based on Haiti’s charcoal consumption of 3,000 metric tons of charcoal per day.

CRI will soon produce between 10 - 15 tons of charcoal a day at its first factory in Cap-Haitien. A minimum of 15 tons per day is the viable production capacity expected for profitability. This is also the realistic goal for the equipment and scope of the initial pilot facility. Future factories in Haiti will be designed and equipped to produce more than 15 tons of briquettes per day.

Considering this production goal, any new successful vetiver charcoal venture should:

1. At scale, produce at least 15 metric tons (MT) of charcoal per day.
2. Sell charcoal at a price no higher than the current price of high-quality wood charcoal. Currently this amounts to 25 gourdes/marmite or 500 gourdes/sack, however inflation and scarcity are already causing prices to increase.
3. Be operational and earning revenue within six months. The longer a program takes to begin operations, the longer and more difficult it will be for that program to troubleshoot issues and improve production and distribution.
4. Prioritize positive social and environmental impact, including a focus on the well-being and development of the community and the health of the environment. A green charcoal initiative should focus on operational efficiencies and product quality, but no aspect of the business



Vetiver plants in La Favette, South Department, Haiti

PART II

Landscape Analysis

Haiti's South ("Sud") Department spans over an area of 2,794 square kilometers, stretching from Tiburon to Côtes de Fer, with a population of around 700,000.¹ Agriculture is the region's largest industry, recognized for having one of the greatest crop varieties in the country. Corn is grown extensively, but the area also produces peanuts, peppers, mangoes, bananas, beans, yams, peas, rice and sorghum, along with a variety of livestock.²

The South has received little attention from international aid groups compared to the rest of the country, likely because the 2010 earthquake had comparatively low impact in the region. Donors such as Norway, IDB and the GEF, in addition to others, have contributed funds for development in the south. The Norwegian Government has contributed a total of \$40 million to development projects in the south.



Vetiver is highly drought tolerant and grows in extremely poor soils

The closest clean cooking fuel or cook stove projects currently underway are Konpay and the Public Private Alliance Foundation's ethanol cook-stoves project. Konpay briquetting technology

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- 1 Haitian Institute of Statistics and Information. (2009). "Population Totale, Population de 18 Ans et Plus Menages et Densites Estimes en 2009."
 - 2 Howell, Holly. (2012). "Working Children in Agriculture in Haiti, Sud Department." United States Department of Labor. ICF International.

and operational model is fashioned after Massachusetts Institute of Technology's Fuel from the Fields initiative, using low-tech machinery and decentralized production.³ The PPAF pilot is at a very early stage and it is unclear when it plans to scale. At the moment, clean cooking projects are being implemented in the South Department, and alternative cook-stoves or fuel sources are very difficult to locate in the region. A recent study by the University of Kentucky surveyed 150 residents in Jacmel and Les Cayes, and found that while half of the participants had received improved cookstoves in the aftermath of the 2010 earthquake, very few of the study participants still use them today.⁴

Côte Sud: Infrastructure and Resources

Les Cayes, the Department Capital and the nation's third largest city, is home to a population of around 75,000.⁵ It is the region's hub for commercial activity and location of the largest vetiver distilleries. The main highway between Les Cayes and Port-au-Prince, Route Nationale 2, is paved and in relatively good condition. With no traffic, a car can reach Les Cayes from the nation's capital in four hours. Semi-regular strikes and protests, as well as major accidents along the route, can dramatically lengthen the trip.

Les Cayes technically has both a port and an airport, but neither is fully operational. The port, operated by the National Port Authority, is used to export sugar, coffee, bananas and vetiver. It is unclear whether the port currently handles any major goods. The city's own vetiver exporters mainly ship through Port-au-Prince.⁶ Les Cayes' Antoine-Simon Airport is currently used only by charter or private planes and does not provide commercial services to Port-au-Prince. In 2013 the city planned to expand the airport's runway and construct a customs terminal to receive international flights, however the project is unlikely to be completed any time in the near future.⁷

The region's electricity is provided mainly by Electricite d'Haiti (EDH), the government owned utility. Power is most reliable in Les Cayes. Even so the city regularly faces long black-out periods.⁸ Electricity is less reliable in rural areas and the utility does not provide beyond Port Salut. Currently, two projects, the Coopérative Electrique de l'Arrondissement des Côteaux (CEAC) and Earthspark International's micro grid located in Les Anglais provide solar-powered electricity to rural families beyond Port Salut. However, these projects will only provide enough capacity for basic household energy consumption, and regardless of where a briquetting factory is located, it will need to supply its own power, most likely utilizing a diesel generator.

Les Cayes has a few large open-air markets and several small general stores, but most machinery or bulk goods would need to be acquired in Port-au-Prince. Critical supplies such as 55-gallon steel

3 Konpay. Alternative Charcoal & Clean Cook Stove Program.

4 Sagbo, Nicaise. (2014). "Economic Analysis and Willingness to Pay for Alternative Charcoal and Clean Cook Stoves in Haiti." University of Kentucky.

5 Mongabay. (2014). Population of Les Cayes, Haiti.

6 Erickson interview with Franck Leger, of Agri-Supply.

7 The Sentinel. (2013). "Sources: There will not be an international airport in Les Cayes, South."

8 The Sentinel. (2014) "Haiti: Thousands protest for electricity in Aux Cayes."

barrels are difficult to find. One depot on Avenue des Quatrechemens quoted a price of 1500 HDG (\$32) per barrel after some negotiation, over three times the cost of barrels in Port-au-Prince and Cap Haitien. This is a significant challenge, as a green charcoal business could require at least 50 barrels a month once at scale.⁹ Agricultural machinery, such as tractors, is also unavailable in the region and would need to be purchased in the capital.

The cost of leasing land in the region is far too variable to predict accurately, and finding available land for a briquetting factory would require further investigation. However, nothing suggests that locating and leasing land in the South would be more difficult than in other regions. Indeed, several old vetiver and sugar cane distilleries, that are now out of commission and possibly available for rent, can be found just outside of Les Cayes on the road to Mercy.

Côte Sud: Charcoal Market

The Côte Sud region produces a large portion of Haiti's charcoal, due to the remaining forest stands in Grand Anse, Nippes and South.¹⁰ The majority of produced charcoal comes from the area between Tiburon and Port-Salut and is made from mangroves, mango, *bois d'homme*, and *campeche*.¹¹ Thousands of rural farmers depend on charcoal production for their primary or secondary income, producing an average of 11 sacks of charcoal each week.¹² This charcoal is sold to a large network of intermediaries who oversee the distribution and sale of charcoal along Route 25 and Extension 2 to Port-au-Prince.

Half of the charcoal produced in the region is sold at local markets. It is estimated that the markets in Les Cayes collectively sell around 15,000 sacks of charcoal each month.¹³ In Les Cayes' largest market, prices do not seem to vary depending on the charcoal quality. Instead, prices are set based on the quantity of charcoal sold, from a *marmite* (approximately 1.1kg), to small, medium or large sacks. In Les Cayes, a *marmite* is sold for 20 HGD, while sacks range from 200 HGD to 500 HGD.¹⁴ Smaller markets surrounding Le Cayes, sell marmites at a slightly higher price-point. Local retailers make a profit of 25 HGD per sack and higher margins are achieved when selling charcoal by the *marmite*.¹⁵

The other half of charcoal produced in the South is sent to Port-au-Prince, via a distribution network of wholesalers.¹⁶ It is estimated that 6,000 bags of charcoal leave Grand Anse each day for the

9 Based on CRI production and material needs.

10 NMFA Project on Forest Energy Supply Chains. (2014). "Haiti Forest Energy Report." Cote Sud Initiative. UNEP Haiti.

11 Ibid.

12 Ibid.

13 Ibid.

14 Erickson market interviews.

15 Ibid.

16 NMFA Project on Forest Energy Supply Chains. (2014). "Haiti Forest Energy Report." Cote Sud Initiative. UNEP Haiti.

capital and it is likely that Sud exports a similar quantity.¹⁷ In various municipalities within Sud, charcoal is sold to Port-au-Prince wholesalers for 200-300 HGD per large sack. These wholesalers spend approximately 75 HGD per sack for transport to Port-au-Prince, where they sell them for 400-470 HGD each, earning a 25% margin.¹⁸ End-buyers of charcoal in Port-au-Prince pay up to 2,000 HGD for large sacks (two bags sewn together).¹⁹

Côte Sud: The vetiver industry

Vetiver [*chrysopogon zizanioides*] is a hearty bunch leaf cultivated throughout the Les Cayes region.²⁰ Vetiver leaves and roots can generate income through their use in the production of cooking or industrial fuel, thatched roofs, and specialty crafts. However, vetiver root oil is by far the most valuable product derived from the plant.



Vetiver is largely cultivated in the South Department of Haiti for the fragrant essential oil distilled from its roots and is an ingredient in most commercial perfumes

Cultivated during the dry season from December to August, vetiver roots grow vertically and can penetrate compacted and dry soils up to 2-4 meters deep, making it uniquely suited for Haiti's

17 Ibid.

18 Ibid.

19 Ibid.

20 Freeman, Scott. (2011). "Vetiver in Southwest Haiti." Columbia University.

eroded farmland.²¹ Vetiver leaves can grow up to 1.5 meters high and can be used for energy, thatched roofs and specialty crafts.²² The optimal maturation time for oil distillation is 12 to 18 months, after which, the root oil production and oil quality decreases.²³ Throughout the growing season, farmers typically trim the vetiver leaf to increase root yield.²⁴ Vetiver leaf is often left on the field to shade the soil and serve as mulch, but can be used as animal feed when fresh.²⁵ When harvested, the leaf is cut at the crown and the roots are dug out and cut from the crown as well. The bare crown is then replanted and covered with the leaves. Harvesting vetiver roots exacerbates soil erosion, especially when entire plots are pulled up at one time or during the rainy season. To stabilize the soil, it is recommended that growing seasons endure a full 12 months and that contour hedges be planted around vetiver plantations while vetiver bands be harvested on an alternate schedule, especially on steeper slopes.²⁶

Haiti's vetiver oil production has fluctuated considerably over the last 60 years. From the 1950s to the 1970s, vetiver oil production and export grew to over 700 drums per year before falling sharply throughout the 1980s and '90s.²⁷ That number has steadily increased over the last few years, and 2015 is believed to be a record high production year, due to a severe drought that lengthened the growing season.²⁸

Vetiver is harvested by smallholder farmers and paid laborers. It is estimated that anywhere from 15,000 to 60,000 farmers rely on vetiver roots as their primary source of income.²⁹ Vetiver is also the most valuable crop for farmers in the region. According to a 2011 study by TechnoServe, a bale ("bal") of vetiver roots was sold for 300 HGD in 2010. Today that price has increased to as high as 575 HGD/bal.³⁰ Yet, because its roots grow to extreme depths in very remote areas, harvesting vetiver root is laborious, and transporting roots to pick-up locations can take up to five hours by horse or donkey. These challenges mean that the cost of labor for landowners and vetiver farmers is high. In 2010, laborers were paid \$3.70-\$6.00 per day of work.³¹

Speculators ("spekiletes") serve as middlemen, buying a truck's worth (~4.5 alembics or 300 bales) of roots from farmers for 97,500 HGD and selling it to oil distillers for 105,750 HGD. Speculators make roughly 8,250 HGD per truckload of vetiver bales.³² Some farmers have relationships

21 Truong, P, Tan Van, T, Pinners E. (2008). "Vetiver Systems Application, Technical Reference Manual". The Vetiver Network International.

22 Ibid.

23 Erickson interview with Jean-Pierre Blanchard.

24 Erickson Interview with vetiver farmers.

25 Ibid.

26 Freeman, Scott. (2011). "Vetiver in Southwest Haiti." Columbia University.

27 Ibid.

28 Erickson interviews with Franck Leger and Jean-Pierre Blanchard.

29 TechnoServe. (2011). "Opportunities in Haiti's Vetiver Industry." On behalf of EcoVenture.

30 Ibid. Old price from TechnoServe analysis, new price from Erickson interview with La Favette Cooperative.

31 TechnoServe. (2011).

32 Ibid.

directly with distillers and bypass the speculators in order to get a higher price. This is expected to become more prominent as farmer cooperatives develop and become an organizing force along the supply chain.

There are currently 6-10 vetiver farmer cooperatives in the South, each representing a distinct growing region and ranging from 35 – 85 active members.³³ The cooperatives have been formed in order to provide producers with training opportunities and higher incomes and increasing industry stability and quality control. Some cooperatives are larger than others, and have closer relationships to distillers, however none of them have the bargaining power to demand a premium price for their roots or regularly monitor farming practices within their community.³⁴ Furthermore, due to farmers' lack of access to capital, distillers reticence to provide cash advances, and a lack of transparency within the industry, there is a great deal of distrust along the supply chain.³⁵

Distillers are responsible for transporting vetiver roots from speculators to the distillery, using dump trucks. It is believed that there are around 60 trucks operating in the region, each with the capacity to hold around 300 bales.³⁶ The number of distilleries region dropped from around 30 distilleries in the 1970s, to approximately 10 in operation today, including three major distillers that also act as exporters: Caribbean Flavors and Fragrance (CFF), Agri Supply, and Unikode.³⁷ The price of exported vetiver oil is around \$80-85 US per pound, or \$39,000 US per barrel when sold directly to perfumeries.³⁸ As the price for vetiver increases on the international market, the cost of roots is also expected to rise. Calculations based on TechnoServe's data indicate that approximately 1800 bales of vetiver roots are needed to produce one barrel of oil or 8,624 bales for one ton of oil. At \$9.46 per bale, the distiller pays a total of \$18,600 for the roots necessary to produce one ton of oil.

33 Erickson interviews with La Flamand and La Favette Cooperatives.

34 Erickson interview with Adrienne Stork, UNEP Haiti.

35 TechnoServe. (2011).

36 Ibid.

37 Erickson interview with Franck Leger.

38 TechnoServe. (2011). "Opportunities in Haiti's Vetiver Industry." On behalf of EcoVenture.

PART III

Feedstock Availability

As stated previously, a charcoal enterprise should produce at least 15 metric tons of charcoal a day at scale. To reach that goal, a charcoal business needs to source roughly 60 metric tons of raw biomass each day, or 16,560 metric tons of biomass a year.¹ This section evaluates four sources of raw material that might be used by a charcoal venture, in terms of availability and cost.

Vetiver roots

It is estimated that vetiver is cultivated on 12,000-15,000 hectares in Haiti in order to produce between 60-85 metric tons of vetiver oil each year.² However, little reliable data is available and distillers tend to swing between being highly secretive about their production rates to drastically overestimating them.³ Franck Leger of Agri-Supply, also known as the Frager Distillery, estimates that he distills around 60 metric tons of roots per day while the region as a whole produces around 100. Assuming this is correct, the Les Cayes region would collectively distill enough vetiver roots on a daily basis



Recently harvested vetiver roots

- 1 Based on CRI's production, bagasse to charcoal yield.
- 2 Alphonse, Roberson. (2014). "Thanks to vetiver, Haiti perfumes the world." *Le Nouvelliste*.
- 3 Erickson interview with Jean-Pierre Blanchard.

to supply a charcoal facility's production from December to August. It would also allow the facility to stockpile a small surplus of roots for charcoal production during the 3-4 month rainy season.

However, this is a very rough estimate (distillers don't measure daily production by volume or weight of roots processed) and likely overstates the region's daily distillation rate by a large margin. UNEP estimates that Haiti harvests 5,000 – 8,000 metric tons of vetiver roots per year.⁴ This would equal to around 42 tons of roots harvested and distilled a day for the entire industry, assuming the average distillery operates 190 days of the year.⁵ Furthermore, Caribbean Flavors and Fragrance reported that as the largest distillery in Haiti, the company distills an average of 15 metric tons of roots/day, yielding 1.5% of that amount in oil. Assuming CFF's root-to-oil yield is applicable to all distillers, Frager's 60 metric tons of roots/day would produce 900 kilograms of oil. Producing 35 metric tons of oil per year, as the Frager distillery claims it currently does, would require the distillery to operate only 39 days a year.⁶

The industry could dramatically increase over the next few years, but it could also be deterred by two significant obstacles that stand in the way of vetiver roots serving as a reliable charcoal feedstock.

1. Vetiver waste is more valuable to distillers as an on-site energy source than as charcoal feedstock:
 - » The largest expense for distillers is energy, representing up to 40% of the operational costs.⁷ Most distillers currently use a crude oil called "mazut" to power their boilers, that costs as much as \$14,000 US per year. Distillers could offset this by using vetiver waste as energy. A study by Techno-Serve analyzed the opportunity cost of using vetiver waste to make charcoal as part of EcoVentures International Haiti Alternative Fuels Project. The study found that using 1 ton of vetiver biomass to fuel a boiler would save around 100 gallons of fuel. At \$2.92 per gallon of mazut, replacing fuel with 30 tons of vetiver roots would save distillers \$8,760 per day. Conversely, it is estimated that 30 tons of vetiver roots would yield 8 tons of charcoal briquettes, and selling that charcoal by the 30 kilo sack for 500 gourdes each would earn the seller \$2,516.⁸
2. It is predicted that once distilleries upgrade technology, their furnaces will consume 100% of the vetiver roots they distill. At least one distillery, CFF, already does so. CFF also expressed a need to augment vetiver waste with other biomass, including trash scraps and sugarcane bagasse. Unikode has also likely begun using vetiver for energy on-site, and Agri-Supply's largest buyers have been pressuring it to do so in order to become more sustainable.⁹

4 Erickson interview with Adrienne Stork.

5 Erickson analysis: Haiti had approximately three weeks of vacation in 2014, and vetiver harvesting is mostly dormant from August to December. Therefore, it should be expected that the vetiver industry operates 5 days a week for 38 weeks, or approximately 190 days of the year.

6 Astier Demarest. "Our Partner: Agri Supply."

7 TechnoServe. (2011). "Opportunities in Haiti's Vetiver Industry." On behalf of EcoVenture.

8 Ibid.

9 Erickson interviews with George Elie and Franck Leger

Based on the fact that vetiver distillers are likely to use all vetiver waste for on-site energy in the near future, distilled vetiver roots do not present a reliable source of biomass for charcoal production.

Vetiver leaves

Several vetiver farmers confirmed that vetiver plants yield more leaves than roots throughout the growing season, and that vetiver leaves would be relatively easy to harvest.¹⁰ However, calculating the amount of leaves produced in Haiti is difficult, as they have no monetary value and there is no major market use for them.

With no reliable data on the number of hectares are devoted to vetiver production in Haiti, or



According to some vetiver farmers, vetiver plants yield more leaves than roots throughout the growing season, and are relatively easy to harvest

vetiver yield per hectare, it is only possible to deduce an approximate range using data proxies. In the Dominican Republic, a vetiver plantation demonstrated a production yield of 40 tons of below- and above-ground biomass per hectare.¹¹ If it is true that vetiver is cultivated on 15,000 hectares in Haiti, this would signify that Haiti is producing up to 600,000 tons of vetiver biomass

10 Erickson interview with La Flamand and vetiver farmers

11 Boucard, Gueric. (2004). "Clean and Cheap Energy Production for Caribbean Islands." Domarome.

per year. However, it should be assumed that Haiti's vetiver farms are yielding far less biomass than a plantation in the Dominican Republic, which uses chemical inputs and advanced farming techniques. It should also be assumed that a large portion of the yield per hectare is below-ground biomass, or the vetiver roots.

Dividing the Dominican Republic plantation's yield per hectare by a third and assuming that half of the biomass grown is actually roots, would indicate that leaf production is closer to 100,000 tons per year.

This is still a healthy quantity of leaf biomass, however, much of it is required on the field as mulch or livestock feed. Haitians use a significant portion of vetiver leaves as a ground cover directly after harvest, when crowns are replanted.¹² Due to its higher silica content, vetiver does not break down easily and can form a thick matt over soil to suppress weeds and keep soil cool.¹³ To a limited degree, vetiver leaves can also serve as feed for livestock. According to a 2013 report published in the Pakistan Journal of Nutrition, vetiver leaf contains optimal protein and mineral content 4-6 weeks after replanting vetiver crowns.¹⁴ Assuming that half of leaf biomass produced throughout the season is needed for mulch and feed would mean approximately 50,000 tons of vetiver leaves would be available for energy.

Purchasing vetiver leaf in bulk at a cost-effective price will be extremely difficult. Vetiver leaf is currently not harvested or aggregated, as growers cut leaves throughout the growing season to increase root yield. Transporting leaves from individual farms to a central location, such as a speculator's house or depot, will require the same time and labor as collecting and transporting roots. This could mean that the cost of leaves may be similar to that of roots; around \$6 per bale, or \$240 per ton (approximately 40 bales equal one 1 ton of biomass). This exceeds a charcoal business' budget for biomass by far, which is closer to \$10 a ton, including the cost of transportation.¹⁵

Based on this information, there are enough vetiver leaves in the Southern region to supply a green charcoal factory. However, the cost of sourcing vetiver leaves may prove too burdensome, and the venture will need to source leaves in a very strategic manner in order to keep input costs low.

12 Erickson interviews with Adrienne Stork (UNEP) and vetiver cooperatives

13 Truong, Paul, Tan Van, Tran, Pinner, Elise. (2007). "Vetiver System Applications. Technical Reference Manual."

14 Falola et. al. (2013). "Nutritional and Anti-nutritional Components of Vetiver Grass at Different Stages of Growth." Pakistan Journal of Nutrition.

15 Erickson analysis based on TechnoServe report. TechnoServe. (2011). "Opportunities in Haiti's Vetiver Industry." On behalf of EcoVenture.

Sugar cane

It is estimated that Haiti produces around 119,000-140,000 tons of sugarcane bagasse per year, however the sugarcane production in the Southern department is negligible.¹⁶ Some farms plant sugarcane along the corridors of their plots and several small cane presses can be seen in remote areas, but only one semi-mechanical sugarcane distillery could be identified in the region, just outside of Cavaillon. The distillery, Clairin Vaval, processes 20 metric tons of cane a day, producing around 3,800 tons of bagasse a year.¹⁷ In and of itself, this is not a large quantity, and Vaval claims to use all of its bagasse either as fuel for the distillery's furnace or for compost. According to the owner, Fritz Vaval, only a handful of farmers produce enough cane for distillation, and growing sugarcane on his own property to augment his supply is necessary. Vaval also reported that while there are several small distilleries in Les Cayes, all of them, with the exception of his, purchase cane syrup from Port-au-Prince or Leogane in order to produce *clairin*.

Based on this analysis, sugar cane is not a reliable source of biomass in the South.



2010 © International Disaster Volunteers

Bagasse is the by-product produced when sugar cane is processed

16 Ministry of Public Works, Transportation and Communications. (2006). "Haiti Energy Sector Development Plan 2007-2017."

17 Erickson analysis, assuming distillery operates 190 days a year.

Corn (Maize)

In 2014, Haiti produced 360,000 metric tons of corn on approximately 600 thousand hectares, far more than other staple crop in the nation, such as rice and beans.¹⁸ The South produces more corn than any other department, and corn yields in the region are believed to be highest in the country.¹⁹ No department-based production information is available for corn, but it is likely that the plains around Les Cayes and the Sud department at large, produce at least one quarter of the country's domestic product, or around 90,000 tons.²⁰ Approximately half of the yield of a corn crop is corn stover (leaves and stalks), which would mean that the South department produces more than 90,000 tons of corn waste a year.²¹

A variety of corn waste products can be used as charcoal feedstock, including the husk, leaves, and shucked cob. However, gaining access to this material will be difficult. Because the bulk of corn meal consumed in Haiti is imported, and very few bulk consumers of Haitian corn exist, harvest schedules are somewhat irregular and corn processing (shucking, kernelling, drying and



The South produces more corn than any other department, and corn yields in the region are believed to be highest in the country

18 Youngblood, Denise. (2015) "Haiti: Country Review." Country Watch.

19 Fintrac, Inc. (2010). "Haiti: Market Analysis." USAID Office of Food For Peace.

20 Erickson analysis based on Fintrac Market Analysis Report.

21 Koundinya, Vikram. (2009). "Corn Stover." AgMRC.

milling) is done by each household rather than at a central facility. It is estimated that 40% of corn grown in the country is sold (either fresh or off the ear, as hominy or maize meal) at regional markets while the rest is consumed at the farm household level.²² The only industrial corn mill in the country is located in Port-au-Prince, and the only one generator-powered mill accessed by only a handful of families for personal use could be located in Les Cayes.²³

It is possible that a supply chain for corn waste could be developed and likely that the cost of corn waste would be cheaper than vetiver waste. Corn is sold for between 7-23 gourdes per pound, based on region and variety, and it is safe to assume corn waste will be sold for less.²⁴ However, estimating the quantity of corn waste and developing a supply chain for it will take significant time and energy. While corncobs are gathered for shucking, cornhusks and leaves are generally left on the field for mulch or livestock feed. Corncobs are a challenging feedstock to work with, due to their high moisture content. While bagasse dries within 1-3 days, corncobs need up to a full week of passive sun drying before pyrolysis.²⁵

Based on this analysis, corn waste is an available and likely cost effective feedstock for green charcoal production in the South. However, the work and time required to develop a corn-waste supply chain may prove too burdensome for a charcoal venture.

22 ibid

23 Erickson interview with mill owners

24 Fintrac, Inc. (2010). "Haiti: Market Analysis." USAID Office of Food For Peace.

25 CRI pilot tests in Central Plateau.

Manioc (Cassava)

Manioc, or cassava, produces a locally available starch that can be used as a binder for charcoal briquettes. No national or regional data on manioc production exists, but manioc is grown by farmers throughout the country and can be purchased in its tuber form at certain markets or in a powder starch form, known locally as “l’amidon,” from bakeries. Sourcing either raw or processed manioc in bulk is very difficult and presents one of the largest barriers to scaling a sustainable charcoal

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The market for manioc is relatively small and the crop is far less cultivated than other staple crops

venture in Haiti. The market for manioc is relatively small and the crop is far less cultivated than other staple crops. In addition, manioc’s growing period can last up to a year, making it difficult to arrange a continuous supply.

Perhaps due to its limited supply, manioc is expensive, costing more than \$800 per ton.²⁶ In the greater Les Cayes region, only two women could be found selling manioc in Valere’s Thursday market. Both women had only a few bundles (6-7 pieces each) available, at a price of 50 HGD.²⁷

To use manioc as a binder, it would be necessary to purchase it in Port-au-Prince or import it at a significant cost.

26 CRI input costs, Cap Haitien.

27 Erickson interview with market vendors.

PART IV

Model Analysis

Recognizing how different aspects of the vetiver industry could impact the operations of a green charcoal business is crucial when evaluating how successful a charcoal initiative is likely in the South. Though there are a myriad ways to structure a green charcoal enterprise around the vetiver industry, any enterprise that produces and sells charcoal must cover three distinct functions:

- Sourcing and carbonizing biomass
- Briquetting charcoal dust
- Distributing and selling charcoal

This section compares three contrasting business models that handle each of these functions differently. Though these three models are not the only means of structuring a charcoal business, they do provide a stark contrast to one another and demonstrate how different approaches impact the cost, timeline, and ability to scale of an initiative.

Model 1: Cooperative-Owned

Model	Biomass Source	Biomass Charring	Briquetting	Charcoal Sales
Autonomous Vetiver-Char Cooperatives	Vetiver leaves brought to coop leaders from farmers, roots from distillers after distillation	Coop char roots and leaves using kilns	Coops briquette char using hand-presses	Each coop sells various quantities of charcoal within the community, no branding

Model

Due to vetiver's decentralized nature and the number of distinct growing regions in the South, a cooperative-owned initiative will likely need to be de-centralized as well. Each vetiver-producing region would form a distinct Vetiver-Char Cooperative, either around an existing producer cooperative or a new entity, such as a community's speculator. Each cooperative would act as an autonomous business, utilizing locally available biomass and selling to local charcoal consumers. After building a regional factory, each cooperative would employ a charcoal team, who would be responsible for a) buying vetiver leaves from surrounding farmers and returned roots from distilleries, b) carbonizing the biomass in 55-gallon barrels, and c) briquetting the resultant charcoal dust using hand presses. Charcoal sales would most likely be based out of the factory as well, though no product brand or

marketing would be involved. Charcoal consumers and independent retailers would come to the factory to purchase charcoal. On average, the charcoal would be sold for 300 gourdes per 30 kg sack.

Benefits

- Provides existing and new vetiver coops more autonomy and control
- Optimizes transportation (distillers' vetiver trucks drop off post-processed roots and pick up newly harvested roots in one trip)
- Lowers cost of input by using locally grown leaves.

Challenges and Risks

- Difficult to scale: It is highly unlikely that a Cooperative-Owned business would reach 15 metric tons a day. Using the best hand-presses currently available, one person can be expected to produce 1000 briquettes a day, or just over one 30-kilogram sack.
- Low quality: Hand and pneumatic presses, as well as mechanical extruders, require little to no electricity. However, the resulting briquettes burn at a lower temperature, create more smoke and ash, and burn for a shorter period.
- Time overruns: After several years of development, the capacity of existing vetiver cooperatives is still limited. Significant funding over the span of at least a year would be needed to organize the first 10 char-vetiver cooperatives. It would then take between six months and a year to hire and train a team of 30-50 people per cooperative, build each factory, acquire all supplies and launch every operation.
- High costs: Aside from the inherent costs associated with longer timelines, regional cooperatives would require far more staff members than other models. Additionally, the cost of supplies, such as hand presses and barrels, will continue to increase, as these supplies would need to be replaced often.
- Rigidity: Cooperatives tend to make high-level decisions slowly. As a market-based enterprise working within in a volatile market, a green charcoal business must be able to adapt to market pressures on a weekly, if not daily basis. Ongoing stakeholder input may compromise the ability to adapt to market pressures on a regular basis.

Model 2: Distiller Owned

Model	Biomass Source	Charring	Briquetting	Charcoal Sales
Distiller-Owned	Vetiver leaves and roots purchased from cooperatives or speculators	Distiller chars using continuous feed pyrolysis machine	Distiller uses briquetting machinery	Distiller sells charcoal to local wholesalers, no branding

Model

Basing the new charcoal operations at its existing facility, the distiller would build an industrial scale factory alongside its existing distillery infrastructure. The centralized factory would handle all aspects of charcoal dust and briquette production, however green charcoal sales would be outsourced to existing charcoal wholesalers. The distiller would use its processed roots as the main source of biomass, up to 400 tons per month, but it would need to use vetiver leaves to augment the production of energy biomass. By increasing the number of drivers and the size of its fleet, the distiller would likely purchase over twice the amount of biomass it currently buys from the same producers it currently works with. The distiller would then use an industrial pyrolysis unit to carbonize the leaves and roots before using an industrial briquette machine to produce high quality briquettes. Once the charcoal is dried and packaged in customary charcoal sacks, it will be sold in bulk to charcoal wholesalers at 400-500 gourdes per 30 kg sack.

Benefits

- Central facility and industrial machinery optimize efficiency and increase the opportunity to scale production.
- Makes use of its existing vetiver supply chain and has the potential to optimize transportation by filling trucks with leaves when roots are not available. The distiller would purchase roots and leaves from the same cooperatives and speculators it currently collaborates with, utilize the same vehicles and drivers, and maneuver the same routes.
- No additional cost of roots for charcoal production

Challenges and Risks

- Justifying the high investment and energy required.
 - » Though they may share a common feedstock, charcoal businesses have little in common with vetiver distillers and exporters. Because of this, launching and managing a vetiver charcoal company would require significant attention and resources. A team of 50 full-time employees would need to handle transportation, pyrolysis, and briquetting, while managers and directors would have to commit to continued learning and improvement.
 - » The earning potential of selling charcoal is far lower than that of vetiver oil. Exporters sell a barrel of vetiver oil for around \$39,000 and with only 10-15% margins, each barrel brings the distiller almost \$6,000. Selling 35 metric tons of oil per year, or approximately 168 barrels, this brings one exporting distillery over \$1 million in profit. Earning this amount of profit would require, at best, 26 months of operating a charcoal factory at scale.¹
- Continued power dynamics between vetiver producers and distillers. Though the distiller would provide an additional source of income to producers throughout the year, as the only leaf buyer, it would also have autonomous control over the purchasing price of leaves. If a vetiver cooperative wished to increase its price of leaves or roots, it might sabotage its relationship with that distiller.

¹ See budget projection for Distillery-owned business in section below.

Model 3: Third Party Ownership

Model	Biomass Source	Charring	Briquetting	Charcoal Sales
Third Party Ownership	Enterprise purchases vetiver roots from various distillers, leaves from coops when needed	Continuous feed pyrolysis machine	Industrial briquette machinery	Enterprise develops brand, sells to wholesalers, institutional buyers and households through depots or mobile retailers

Model

Similar to the distiller-owned model, the third Party enterprise would utilize a central production facility with industrial machinery to increase efficiency and improve quality control. Unlike the Distiller, the third Party would operate at a distinct facility and take a proactive role in the marketing and sales of charcoal.

Located near Les Cayes, the third Party would purchase vetiver roots from a host of local biomass suppliers and augment that supply with leaves only when necessary. After carbonizing and briquetting the vetiver waste at the facility, briquettes would be packaged in sacks and smaller branded *marmites*. A dedicated sales team would build a marketing and branding plan and then pursue various sales opportunities, including contracts with institutional buyers (local NGOs, hospitals and schools), in bulk to wholesale charcoal distributors, and in smaller quantities to mobile retailers via charcoal depots. The third Party would sell sacks of charcoal for 500 gourdes and marmites for 20-25 gourdes.

Benefits

- An independent third party is solely focused on launching and managing a sustainable charcoal business and thus, the business is likely to reach scale at a faster pace.
- Focus on branding and marketing, which has proven to be effective in creating a favorable image among consumers while increasing margins.
- The ability to partner with multiple distillers at once would increase access to local vetiver roots and other biomass sources, decreasing the cost of transport.
- A third party has the potential to improve the dynamic between vetiver producers and distillers.

Challenges and Risks

- As a new entity, finding land and opening a new facility may delay the launch.
- Gaining the trust of vetiver producers and distillers would require a tactical approach adapted to industry politics.
- Optimizing transportation of leaves is difficult. Though it is possible that a distiller would be willing to partner with the third Party to share or lease trucks or tractors, it is more likely that the new company would have to purchase and maintain its own fleet.

Part V

Model Milestones and Costs

The benefits and drawbacks of the three contrasting models are clarified further by evaluating the expected costs and timeline associated with each model. This section compares the expected budgets and schedules attributed to key project milestones for each model to better assess their likelihood of reaching scale and remaining financially sustainable.

Methodology

To project the timeline and costs associated with each model, distinct milestones based on their structure and capacity were determined for each model. The timelines for many milestones are aspirational, as it is assumed that the lessons learned from CRI's pilot will help to accelerate project development and growth for all three models. Furthermore, costs of goods are largely reflective of CRI's expenses are considered:

1. Construction
2. Personnel
3. Major supplies and machinery
4. Cost of biomass
5. Marketing (only applies to third Party)
6. Land (only applies to third Party)

The cost of biomass is the most difficult variable to ascertain at this time, especially because it greatly depends on the cost of transportation. To control for this, the cost of vetiver leaves and roots, as well as binder material is constant among the three models. The quantity of biomass purchase, and the makeup of biomass used (portion of supply is leaves vs. roots) can be considered variables that differ from one model to another.

Assumptions

To simplify budget accounting, all three models assume:

- Grant funding will cover all costs leading up to the final milestone. Funding received throughout this time will not be paid back and will not accrue interest.
- Inflation is not factored in. Haiti's current rate of inflation is high and therefore, the net present value of revenues will likely be lower than what is expressed here.
- Depreciation of assets is not considered, as the budget presents an estimate of launch costs, not operating cost and company value.
- Each model will cover minor expenses with \$5,000 per month.
- All models are able to sell the charcoal they produce. Though the variation in quality and sales strategies are reflected by the prices at which each model sells its charcoal, it is assumed that there is enough demand for green charcoal to allow all three models to sell their product.
- An exchange rate of 53.0 is used when translating from Haitian gourdes (HTG) to US dollars (\$US).

Findings

The following table provides an overview of how the models compare in terms of time needed to reach their respective milestones, project costs, and positioning in terms of monthly profit or loss moving forward. To view the complete accounting of all milestones for each model, see Appendix A.

Of the three models, the third Party Ownership reaches production scale (15 tons/day) in the shortest amount of time and provides the highest monthly return moving forward. Although the third Party and the Distillery are very similar on the production end, their divergent sales strategies set them apart and allow the third Party venture to increase margins.

The Cooperative-Owned model is the least successful due to associated high costs, low productivity, and low revenue. The model's largest expense, by far, is personnel (almost \$80,000 per month). These input costs are not covered by the sale of charcoal, as technological barriers keep the business from exceeding 10 tons of charcoal per day, and the low quality char cannot be sold for more than 300 HGD per sack.

Model	Cooperative Owned	Distiller Owned	Third Party Owned
Final milestone	Produce & sell 6,000 sacks of charcoal/month (10 tons of charcoal/day)	Produce & sell 10,000 sacks of charcoal/month (15 tons/day)	Produce & sell 6,000 sacks & 120,000 marmites/month (15 tons/day)
Notes	<ul style="list-style-type: none"> • Sell by the sack to rural wholesalers, retailers, households • Use 360 tons roots per month, 360 tons leaves day • Selling charcoal for 300 HGD/ 30-kilo sack 	<ul style="list-style-type: none"> • Use 400 tons of roots per month, 840 tons of leaves • Reach 150 wholesalers • Selling charcoal for 450 HGD/ 30-kilo sack 	<ul style="list-style-type: none"> • Reach 100 wholesalers, 150 retailers • Use 1000 tons of roots per month, 200 tons vetiver leaves • Selling charcoal for 500 HGD/ 30-kilo sack, 20/marmite
Total time	60 months	27 months	19 months
Total cost (\$US)	\$3.95 Million	\$1.66 Million	\$1.5 Million
Future monthly cost (\$US)	\$101,111	\$57,233	\$59,475
Future monthly revenue	\$50,943.40	\$84,905.66	\$101,886.79
Future monthly profit/loss	-\$50,168.43	\$27,672.33	\$42,411.46

Technical Analysis – Vetiver Charcoal

Background

Vetiver has been recognized as a promising feedstock for charcoal for several reasons. First, vetiver biomass production is high in the tropics and plantations have demonstrated yields 120 metric tons of dry matter per hectare or more.¹ Second, vetiver leaf has high calorific value, demonstrating an energy value of 16.3 GJ t⁻¹, or 7,000 btu per pound (a higher caloric value than most biomass found in Haiti (dry wood = 19.8 GJ/t; sugar cane bagasse = 9.3 GJ/t).² Third, vetiver yield is reliable, as vetiver is resistant to pests, diseases, fire, and is extremely drought-tolerant.³

While many academic reports and international aid forums tout the promise of vetiver for charcoal production, very few organizations have actively tested it. MIT's D-Lab experimented with vetiver as a charcoal feedstock in Haiti over 10 years ago as part of their "Fuel from the Fields" program, but found that carbonization was uneven during pyrolysis and the dirt on un-distilled vetiver roots decreased pyrolysis efficiency.⁴

In 2011, as part of their "*Haiti Sustainable Vetiver Initiative*," EcoVentures partnered with a European perfume company and several distillers, including Unikode and Celex Oil, to assess the feasibility of using vetiver waste for cooking briquettes.⁵ The proposed program was structured so that oil distillers would use half of their distilled roots for on-site energy, and briquette the other half on-site. The distillers would then sell the briquettes back to cooperatives, who in turn, would carbonize the briquettes and sell them as charcoal in their communities.

As mentioned previously, TechnoServe analyzed the project and determined that the briquette portion of the business did not provide enough value to the distillery. The report did not take issue with the sizable redundancies in the business model, nor did it identify the technological challenges of charring raw biomass pucks - an approach that does not typically produce high quality fuel.

Using a more advanced briquetting technique known to produce high quality charcoal, CRI tested vetiver grass and leaves as a charcoal energy source by pyrolyzing and briquetting vetiver char, and cooking with vetiver briquettes.

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- 1 Pinner, Elise. (2014). "Vetiver System: Reversing Degradation On- and Off Farm, To Keep Soil Carbon In Place, Build UP Roots Biomass, and Turn Degraded Areas in Biofuel Sources." Green Cycle Consulting Ltd.
 - 2 Grimshaw, Dick. (2009). "Vetiver Energy." The Vetiver Network International Blog.
 - 3 Ibid.
 - 4 Erickson interview with Dan Sweeney, D-Lab, Massachusetts Institute of Technology
 - 5 EcoVentures International. (2010). "Rapid Assessment of the Impact of the Earthquake on the Haitian Vetiver Sector."

Trial Methodology⁶

Collecting and Preparing Biomass

CRI tested the efficacy of vetiver roots and leaves as charcoal feedstock at its factory in Cap-Haitien. Vetiver leaves and roots were obtained from the Frager vetiver distillery on August 17, 2015, 12 days after the roots were processed. The exact quantity of biomass received was unknown. The Frager distillery did not charge CRI for the roots, but they did charge 20,000 HTG for providing the leaves, which were collected especially for the purposes of the study.

Though the roots and leaves were dry upon arrival to CRI's factory, an accurate estimation of the minimum time needed to fully dry vetiver biomass was not possible to obtain. Before pyrolysis, the roots and leaves were shaken to remove as much residue as possible, however, because of the density of its matted root system, some dust and small rocks were still coating the vetiver roots.

Analysis

To test vetiver roots and leaves as charcoal feedstock, CRI analyzed vetiver's performance at several stages:

Pyrolysis (Charring): Using 55 gallon drums to pyrolyze the raw vetiver material, CRI tested 10 distinct batches to compare their burn-times, yields, smoke output and the quality of char produced. A high-quality energy biomass will yield at least 20% of its original mass in fully carbonized mass. The batches were as follows:

- Six "All Root" burns
- Three "All Leaf" burns
- Two "50:50" burns of 50% roots and leaves

Briquetting: CRI compared the composition and dry time of four distinct char batches throughout the briquetting process. Each batch contained the same quantity of binder material, and was briquetted using the same machinery and process. The batches were as follows:

- One root char batch
- One leaf char batch
- One leaf/root char batch
- One root/bagasse char batch

Cooking: CRI compared the four batches of briquettes (composed of root, leaf, root/leaf, root/bagasse char) in terms of ease of ignition, heat output, heat duration, smoke output and ash production. Due to a lack of sophisticated temperature gauges, CRI staff tested the strength and duration of heat output using the following methods:

1. Strength of heat output – Time needed to boil one liter of water
2. Duration of heat output – Time until charcoal burnt out as ash

6 A full outline of the methodology used can be found in Appendix B

Trial Findings

Pyrolysis

The burn times for the six “All Root” batches ranged from 105 to 130 minutes. The “quality” (carbonization of the final product) of the root char was given a 3 out of 5 points for all six batches, meaning that some pieces of un-charred root and residue remained. Burn times for the three “All Leaf” batches range from 47 minutes to 65 minutes. Each batch of all-leaf char was given a score of 5 out of 5 points, meaning that all of the material was evenly charred. Burn times for the two 50:50 batches were 66 minutes and 74 minutes, both resulting in a quality score of 4.

All batches produced equal amounts of smoke (similar to the amounts observed for sugarcane bagasse) and produced approximate char yields, around 25% of original biomass volume per drum.

Briquetting

After mixing each batch with CRI’s binder, all four char compositions (root, leaf, root & leaf, root & bagasse) produced a briquette paste consistent with that of sugarcane bagasse. Once pressed into briquettes however, the briquettes containing all-root char appeared the least consistent, likely due to the inclusion of dirt and small rock fragments. The all-leaf batches appeared to be highest in quality (highly dense and consistent). Despite the variation in density and appearance, all four batches took 5 days to dry with passive sun drying.

Once dried, the root-only batch of briquettes weighed 2.8 kg per 100 briquettes, while the root/leaf briquettes weighed 2.9 kg, and the leaf-only briquettes weighed 1.4 kg. The lighter weight of the leaf-only briquettes signified a higher quantity of fully carbonized biomass and a lower quantity of un-charred sediment, such as dirt.

Cooking

Following an hour of attempts to light the all-root charcoal briquettes, they were still not able to fully ignite. The batch containing half root and half sugarcane bagasse char was able to ignite, but was only able to stay lit for 10 minutes. It is believed that this is due to the high content of dirt and other residue in the briquettes. Conversely, the briquettes made from vetiver leaves performed very well. The vetiver batch was able to fully ignite within 5 minutes, boil one liter of water within seven minutes, and stay ignited for 75 minutes before turning to ash. This is comparable to wood charcoal and CRI’s green charcoal made from sugarcane bagasse.

The results of the cooking trials suggest that unless the roots are thoroughly washed using a high-pressure system, vetiver roots cannot be used to produce green charcoal. Conversely, vetiver leaves are an excellent feedstock for charcoal production.

PART VII

Recommendation

Due to the poor performance of the vetiver root briquettes, and the likelihood of vetiver distillers using the bulk of their root waste for on-site energy, it is **not recommended** to use vetiver roots as green charcoal feedstock.

In the event that Haiti's vetiver industry increases dramatically over the next five years, access to vetiver roots may become less of a concern, even if the largest distillers upgrade their boilers to use vetiver waste for on-site energy. Yet, the need to wash vetiver roots after distillation in order to effectively pyrolyze them makes vetiver root a non-viable feedstock. The quantity of water and energy needed to clean the roots would likely offset the positive environmental impacts of replacing wood charcoal with vetiver charcoal.

Unlike vetiver roots, vetiver leaves present an effective energy source for sustainable charcoal production. Without the need to wash away sediment, vetiver leaves char easily and cook effectively once pressed into briquettes. Furthermore, it is estimated that vetiver leaves are produced in abundance, at a rate higher than vetiver roots and other energy biomass found in Haiti. Still, sourcing vetiver leaves would likely be difficult and costly. Training a critical mass of farmers to sustainably harvest and aggregate waste leaves would take time. Because vetiver is grown on remote hillsides, the cost and logistical burden of transporting the leaves to an urban facility would be expensive. To source leaves in a cost-effective manner, a ton of leaves would need to be purchased for \$10 or less. The cost of obtaining 0.25 tons of leaves for the technical analysis of this report, not including transportation, was 20,000 HTG, or \$377 US. Though purchasing directly from vetiver growers would significantly reduce this price, farmers may still expect a price comparable to that of roots, estimated at \$8.80-9.50 per bale, or \$360 per ton.

Regardless of the biomass source, should a vetiver charcoal initiative move forward in the future, CRI recommends that a third party manage it. The ability of an independent enterprise to focus on distinct aspects of the business, including manufacturing, marketing and sales, will enable the initiative to scale more effectively. With regard to manufacturing charcoal, the pyrolysis and briquetting machinery needed to scale production is currently imported. Sourcing and managing this technology will require experience and continued research and development. With regard to sales, it has been demonstrated that branding and marketing is necessary to increase demand for green charcoal. CRI found charcoal sales to dramatically increase after unveiling the "Chabon Boul" brand, that customers report to have learned about from radio advertisements, signage and promotional events. It is unlikely that decentralized cooperatives or preoccupied distillers will be able to manage an effective marketing strategy as it increases productivity.

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APPENDIX A

Detailed estimate of milestone costs for each business model

Model	Milestone 1: Form 10 Char-Vetiver Cooperatives	Milestone 2: Construct Char Factories and Acquire Machinery	Milestone 3: Train Core Staff	Milestone 4: Identify sources of inputs, begin production	Milestone 5: Source 20 tons of biomass/day	Milestone 6: Sell 3,000 sacks/month	Milestone 7: Form 10 new cooperatives	Milestone 8: Construct New Char Factories, Acquire Machinery	Milestone 9: Train New Core Staff	Milestone 10: Identify new sources of inputs, begin production	Milestone 11: Source 40 tons of biomass/day	Milestone 12: Sell 6000 sacks of charcoal/month
Cooperative Owned	Identify communities (evaluate leaf production), Attract members	500 55-gallon drums	1 char manager, 1 briquette manager, 1 sales manager per coop (30 total)	Organize producers and purchase leaf, agree on root price w distilleries	Source 2.16 tons of biomass per day/coop	Produce 360 sacks per coop	Identify new communities (evaluate leaf production)	500 55-gallon drums	1 char manager, 1 briquette manager, 1 sales manager per coop	Organize producers and purchase leaf, agree on root price w distilleries	Source 2.16 tons of biomass per coop per day	10 tons of charcoal/day
	Elect leaders and identify 30 staff/cooperative	200 briquetting presses		Identify sources of binder	Continued outreach to farmers and distillers	Sell to rural retailers and households	Elect leaders and recruit members	200 briquetting presses	30 staff per coop	Identify sources of binder	Continued outreach to farmers and distillers	Sell to rural wholesalers, retailers, households
Milestone Time (month)	5	10	4	5	8	3	3	6	2	5	8	1
TOTAL TIME (months)	5	15	19	24	32	35	38	44	46	51	59	60
Milestone Cost	\$95,000.00	\$334,000.00	\$190,050.31	\$242,850.39	\$413,940.63	\$167,917.74	\$167,917.74	\$769,910.94	\$185,303.65	\$475,949.12	\$808,894.59	\$101,111.82
TOTAL COST (\$US)	\$95,000.00	\$429,000.00	\$619,050.31	\$861,900.71	\$1,275,841.34	\$1,443,759.07	\$1,611,676.81	\$2,381,587.75	\$2,566,891.40	\$3,042,840.52	\$3,851,735.11	\$3,952,846.93
MONTHLY REVENUE	0	0	0	0	\$16,981.13	\$25,471.70	\$101,886.79	\$101,886.79	\$33,962.26	\$101,886.79	\$156,226.42	\$50,943.40
TOTAL REVENUE	\$0.00	\$0.00	\$0.00	\$0.00	\$16,981.13	\$42,452.83	\$144,339.62	\$246,226.42	\$280,188.68	\$382,075.47	\$538,301.89	\$569,245.28

Model	Milestone 1: Acquire critical machinery and Hire Staff	Milestone 2: Train Staff	Milestone 3: Process 150 tons biomass/month	Milestone 4: Identify Sources of Leaf	Milestone 5: Source 600 tons of biomass/month	Milestone 6: Sell 250 sacks/day (7.5 tons)	Milestone 7: Source 1200 tons of biomass/month	Milestone 8: Produce & sell 10,000 sacks of charcoal/mo (15 tons/day)
Distillery-Owned	Pyrolysis & briquetting machinery	10 managers	Use roots as biomass (goal to process 150 tons/month)	Work with partner speculators/coops to train farmers to harvest/gather leaf	60% roots, 40% leaf: 360 tons of roots & 240 tons of leaf per month	Reach 40 wholesale customers	30% roots; 70% leaf (400 tons roots, 840 t leaf)	Reach 150 wholesalers
	1 dump truck	45 facility staff (fluid production line)	Find source of binder, experiment with recipes			Continue reaching new sources of leaf	May require other raw biomass or roots from other distillers	Use 400 tons of roots per month, 840 tons of leaf from farmers
	1 multi-purpose vehicle		Identify issues within ops	Identify wholesalers, begin selling samples	Goal: Sell 1/4 of product (1250 sacks/month)	Continue processing 600 tons biomass		
				Continue processing 150 tons/month			Goal: increase sales to 300 sacks/day	
Milestone Time	6	1	2	5	4	4	4	1
Total Time	6	7	9	14	18	22	26	27
Milestone Cost	\$775,000	\$30,833	\$66,167	\$165,416.67	\$168,933	\$168,933	\$228,933	\$57,233
Total Cost	\$775,000.00	\$805,833.33	\$872,000.00	\$1,037,416.67	\$1,206,350.00	\$1,375,283.33	\$1,604,216.67	\$1,661,450.00
Monthly Revenue	0	0	0	0	\$42,452.83	\$169,811.32	\$203,773.58	\$84,905.66
Total Revenue	0	\$0.00	\$0.00	\$0.00	\$42,452.83	\$212,264.15	\$416,037.74	\$500,943.40

Model	Milestone 1: Acquire land and critical machinery, construct factory	Milestone 2: Hire and Train Core Staff	Milestone 3: Identify sources of inputs, begin production	Milestone 4: Identify Brand and Begin Marketing & Sales	Milestone 5: Source 150 tons of biomass/ week	Milestone 6: Sell 250 sacks/day (7.5 tons)	Milestone 7: Sell additional 4,050 marmits/day	Milestone 8: Source 300 tons of biomass/ week (1200 /month)	Milestone 9: Sell 300 sacks & 6,000 marmites a day (15 tons)
3 rd Party	Pyrolysis & briquetting machinery	10 managers	Purchase roots from 2 distilleries (goal = 150 tons/month) and binder	Brand packaging	100% roots. Sign purchasing contracts with all major oil distilleries (50t/week from largest, 10-20t/ week from smaller)	Reach 50 wholesalers and institutional buyers	Reach 75 retailers	250 tons of roots from distillers, 50t vetiver leaf from 5 coops	Reach 100 wholesalers, 150 retailers
		45 facility staff (fluid production line: staff trained in all aspects of production)		Begin advertising					
	2 dump trucks, 2 multi-purpose vehicles		Begin operations and optimize production line	Sales training	Begin pursuing cooperatives	Source 200 tons biomass per week (100% roots)	Begin purchasing from cooperatives	Goal to sell 300 sacks, 4,050 marmites charcoal/ day	Selling charcoal for \$500 grd/ 30- kilo sack, \$20 grd/ marmite
Milestone Time	6	2	1	1	2	1	2	3	1
Total Time	6	8	9	10	12	13	15	18	19
Milestone Cost	\$891,000	\$63,667	\$35,133	\$35,883	\$78,367	\$50,183	\$110,367	\$178,426	\$59,475
Total Cost	\$891,000.00	\$954,666.67	\$989,800.00	\$1,025,683.33	\$1,104,050.00	\$1,154,233.33	\$1,264,600.00	\$1,443,026.00	\$1,502,501.33
Monthly Revenues	0	0	0	0	\$28,301.89	\$47,169.81	\$155,471.70	\$174,339.62	\$101,886.79
Total Revenues	0	\$0.00	\$0.00	\$0.00	\$28,301.89	\$75,471.70	\$230,943.40	\$405,283.02	\$507,169.81

APPENDIX B

Full Methodology and Results from Vetiver Charcoal Trials

Step 1: Pyrolysis:

Prepare Biomass:

- Note days between distillation and pyrolysis and moisture level of raw roots and grass (use moisture reader if available)

Test 10 barrels of biomass:

- 6 batches all post-processed roots
- 3 batches all leaves
- 2 batches mixture leaves/roots

Note char quality, yield and burn time, smoke for each batch:

Batch	Char Time	Char Yield (resulting Kg/ barrel)	Char Quality	Notes (smoke output, etc.)
Batch #1 Root	2 hours	5.6 kg	3	"normal smoke"
Batch #2 Root	1 h 45 m	5.55 kg	3	""
Batch #3 Root	2 h 10 m	5.6 kg	3	""
Batch #4 Root	1 h 58 m	5.5 kg	3	""
Batch #5 Root	1 h 56 m	5.6 kg	3	""
Batch #6 Root	2 h 03 m	5.57 kg	3	""
Batch #1 Leaf	54 m	3 kg	5	""
Batch #2 Leaf	1 h 05 m	2.7 kg	5	""
Batch #3 Leaf	47 m	2.9 kg	5	""
Batch #1 Root/Leaf	1 h 06 m	5.6 kg	4	""
Batch #2 Root/Leaf	1 h 14 m	5.6 kg	4	""

Step 2: Briquetting:

In small batches, test briquettes as follows:

- 1 batch vetiver root char
- 1 batch leaf char
- 1 50:50 batch leaf/root mix char
- 1 50:50 batch vetiver root/bagasse char

Note consistency/texture after mixer, look, texture, density after briquetting, drying time, and density of dried briquette:

Batch	Consistency after mixer	Consistency after briquetting	Drying time	Weight of 100 dried briquettes
Batch #1 Root	Fine	Inconsistent	5 hours	2.8 kg
Batch #2 Root/Bagasse	""	Inconsistent	5 hours	2.0 kg
Batch #3 Root/Leaf	""	Inconsistent	5 hours	2.8 kg
Batch #4 Leaf	""	Very good	5 hours	1.4 kg

Step 3: Cooking Trials:

Use each of the 4 batches from Step 2 to test ease of ignition, strength of heat output (time to boil), duration of heat output, smoke output, ash production and overall satisfaction:

Batch	Time to ignite	Time to boil 1 liter water	Time of burn	Smoke output	Level of ash	Overall satisfaction of cooks
#1 Root Briquettes	N/A	N/A	N/A	N/A	N/A	Did not work
#2 Root/Bag. Briq.	Difficult	N/A	N/A	N/A	N/A	Did not work
#3 Root/Leaf Briq.	N/A	N/A	N/A	N/A	N/A	Did not work
#4 Leaf Briquettes	5 min	7 min	1 h 15 m	Normal	Normal	Works well