CHARCOAL IN HAITI

A National Assessment of Charcoal Production and Consumption Trends

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Executive Summary and Key Findings

A widely cited report from 1979 suggested that existing wood supplies in Haiti would be enough to meet increasing charcoal demand until around the year 2000, but that ongoing charcoal production could result in an environmental 'apocalypse' (Voltaire 1979, 21, 23) The prediction that wood supplies in Haiti would be exhausted by 2000 was also supported by a report on trends emerging from early remote sensing analyses of aerial photographs spanning from 1956 to 1978, for three different locations in Haiti (Cohen 1984, v–iv). And yet, some 40 years later, Haitians continue to produce large quantities of charcoal despite these dire predictions to the contrary.

The research presented in this report directly addresses important and unresolved questions stemming from the unexpected fact that Haitians continue to meet approximately 80 percent of their national energy needs through firewood and charcoal production:

1. How much charcoal is consumed annually in the capital city of Port-au-Prince?
2. Which geographical regions produce the charcoal consumed in the capital?
3. How do these production areas variably supply charcoal to the capital?
4. In what ways have these trends changed over time? and
5. What percentage of charcoal is originating from the bordering Dominican Republic?

This report draws on research spanning nearly half a century to answer these questions, presenting both longitudinal and cross-sectional data related to multiple aspects of charcoal production and consumption in Haiti. Data collection spanned two years, commencing in 2016 with literature reviews, key informant interviews, and regional scouting trips across Port-au-Prince and Haiti to identify the best locations to position research teams with the objective of enumerating passing charcoal trucks and boats. These preliminary stages were followed by three different periods of roadside sampling to count passing trucks (August 2017, October 2017, and December 2017) that amounted to a total of 384 hours of observations, registering 10,404 unique enumerations of charcoal vehicles by 69 enumerators placed at 23 different roadside stations that controlled charcoal vehicles at multiple intersections of roads or maritime wharfs leading into Port-au-Prince from every direction of the country.[1]

The estimations and subsequent extrapolations presented here are conservative, using midrange estimates on a number of variables, including charcoal bag carrying capacities for different-sized vehicles in the classificatory typology, an average weight assumption for charcoal bags, and the utilization of annual extrapolation methods (for Port-au-Prince and all of Haiti) based on extending data sampled during representative low and peak periods of charcoal production to corresponding low and peak seasons across the entire year.

This research provides targeted answers to a narrow set of research questions, helping to fill an important information gap in Haiti. Most notably, the total volume of charcoal moving into Port-au-Prince has implications on the total required *volume* of primary production of biomass for charcoal and the total *value* of the charcoal value chains, demonstrating the magnitude of importance of charcoal production for Haiti. These two up-to-date figures may inform policy decisions for development and government programming related to landscape management, reforestation, tree planting, agroforestry, and agricultural projects in Haiti.

[1]The research design also controlled for every known and relevant vehicular point of entry from the Dominican Republic at the time of the research. The authors acknowledge that charcoal may be entering Haiti from Route National Number 6, along the northern coast of Haiti, or through wharfs along the northern coast of Haiti (the only known major entry routes not controlled for). However, such charcoal would most certainly be headed to the nearby city of Cap Haitian, or other urban towns north of Haiti.

Key Findings and Conclusions

The data and analyses permitted conclusions and estimates that help contextualize the enormity of charcoal production in Haiti in terms of scale, geographic scope, economic impact, and employment generation. All key findings and conclusions briefly summarized here are supported in more detail in the main body of the report.

The main findings of the research are:

- ***Approximately 438,000 metric tons of charcoal are consumed annually in Port-au-Prince.*** The annual charcoal consumption range for *Port-au-Prince* is based on 24/7 counts at six key enumeration stations controlling for the largest known charcoal entry points into the capital. Extrapolating from two weeks of sampling data (one week of sampling data from a peak charcoal production season and one week from a low production season), an estimated 352,014 to 524,394 metric tons, with a midrange estimate of **438,204 metric tons of charcoal** are consumed annually in Port-au-Prince.
- ***Approximately 946,500 metric tons of charcoal are consumed nationally in Haiti each year.*** The estimated annual charcoal consumption range for Haiti at the *national* level is based on a *tons-to-population* ratio created from the annual estimate for Port-au-Prince—by far the largest city and largest consumer of charcoal in the country. The tons-to-population ratio was applied to the entire urban population of Haiti[2] (inclusive of Port-au-Prince) as last reported by the Haitian government (IHSI 2015), suggesting a range between 759,470 and 1,133,537 metric tons, with an estimated midpoint of **946,506 metric tons of charcoal** consumed nationally in Haiti each year.
- ***Charcoal production is the second-largest agricultural value chain in Haiti.*** The charcoal sector's outsized influence on Haiti's economy is evidenced by its size relative to other agricultural commodities. It is the second largest agriculture value chain in the country, behind only mangoes, and dwarfing most other traditional pillars of the Haitian rural economy, such as yams, bananas, beans, avocados, coffee, sugarcane, and corn.
- ***Contrary to popular conception, the data show that a negligible amount of the charcoal consumed in Port-au-Prince, Haiti, originates in the Dominican Republic.*** Across five different enumeration stations controlling for charcoal entering Haiti from the Dominican Republic, the total amount of charcoal observed in the research presented in this report is equivalent to 2.48 percent of the amount consumed in Port-au-Prince during that same period.[3]

Other key findings include:

- ***Researchers are approaching consensus that current arboreal land coverage in Haiti is significantly higher than previously believed.*** Since the early 1980s, the Haitian government has stated that in ideal conditions (given realities of topography, geology, and meteorology) some 35–55 percent of the land surface of Haiti should be covered forests. Five recent land-cover studies have concluded that Haiti has a much higher than conventionally reported level of tree cover and/or forest cover,[4] with many reports estimating present tree coverage in Haiti at approximately 30 percent of the land surface.
- ***There are clear annual low and peak seasons of charcoal production in Haiti.*** Evidence presented here demonstrates that charcoal production fluctuates significantly during the course of a year; there are clear peak and low seasons of charcoal production, typically lasting approximately six months each. Unexpected events such as disasters, droughts, agricultural pests, tropical storms, or political unrest—which disrupt the traditional agricultural calendar—may shift, shorten, or extend low and peak charcoal production seasons

[2]Charcoal is primarily produced rurally and consumed in urban locations. In rural locations Haitian use firewood for cooking.

[3]These data are supported by other research, suggesting that the percentage of official charcoal exports from the Dominican Republic to Haiti has declined significantly over the last two decades, while Dominican exports to overseas markets have surged. In 2001, Haiti received over 50 percent of official Dominican charcoal exports, which were valued at only US$4k. By 2012, the value of Dominican charcoal exports had grown to between US$500,000 to US$1,200,000, and exports were exclusively to the U.S., Europe, and the Middle East, indicating new charcoal markets of higher value were found elsewhere.

[4]Definitions of forest and tree cover vary, but controlling for differences in definitions, many studies converge at or near 30 percent.

in Haiti. It is likely that market fluctuations—either of price or of supply and demand—have a similar effect.

- ***Charcoal production in Haiti is now decentralized throughout the country.*** The addition of approximately 1,200 new feeder roads (remote, smaller roads that later join national highways) since the late 1960s and improvements to existing roads have opened up most remaining areas in the country and permitted the decentralization of charcoal production in Haiti.
- ***The national decentralization of charcoal production in Haiti has resulted in less pressure on some traditional production areas, permitting arboreal recovery and subsequent return to charcoal production.*** Although charcoal production has reached most corners of the country, decentralization has relieved pressure on traditional production areas, permitting natural arboreal regeneration and a return to increased charcoal activities.
- ***The differential supply of charcoal to Port-au-Prince by region has shifted over time as a function of the influences of decentralization, changes to transportation, and arboreal recovery in historical production zones.*** Presently, the following geographical regions differentially supply charcoal to Port-au-Prince. The relative contributions from the following regions represent all the charcoal consumed in Port-au-Prince during our combined sampling periods: northwest (1%); island of La Gonâve (3.4%); Artibonite (9.7%); Central Plateau (20.3%); east of Port-au-Prince (18%); the southern (Tiburon) peninsula (41%); southeast (4.2%); due south of Port-au-Prince/Kenscoff/Furcy (0.1%); and the Dominican Republic (2.3%).
- ***Regionally, the largest charcoal supplier to Port-au-Prince is the southern peninsula, and the three top charcoal production locations together produce approximately 80 percent of the charcoal consumed in Port-au-Prince.*** The Tiburon peninsula registered 41 percent of the total charcoal supplied to the capital. This position as the largest regional supplier of charcoal to Port-au-Prince has remained above 30 percent since 1978. The second and third largest suppliers of charcoal to the capital are the Central Plateau (20.3%) and the area east of Port-au-Prince (18%). Together with the southern peninsula (41.0%), these top three locations supply nearly 80 percent of the charcoal consumed in the capital.
- ***The volume of charcoal counted at the farthest, most remote enumeration stations registered an amount equivalent to one-half of the total amount entering the capital.*** The four enumeration stations farthest from Port-au-Prince registered an amount of charcoal equivalent to approximately half the charcoal consumed in the capital during the same time period, demonstrating that high volumes of charcoal production occur at the far reaches of the country.
- ***The amount of charcoal emerging from areas penetrated by feeder roads established since the late 1960s is equivalent to approximately one-third of the quantity consumed in the capital during that same period of time.*** These 'feeder roads' demonstrate the high level of decentralization of charcoal production in Haiti and the production capacity of these remote locations.
- ***Maritime charcoal transport in Haiti has decreased in significance.*** While historically boats carried large percentages of charcoal into Port-au-Prince, data presented here show the total volume of maritime charcoal counted at the wharfs sampled at an amount equivalent to 6.7 percent of the charcoal consumed in the capital during the same period. This is likely a result of new and improved roads and road transport.
- ***The <u>overall</u> production of charcoal has increased in all geographical areas of Haiti, even as <u>relative</u> supply of some areas has decreased.*** The annual estimate for charcoal consumed in Port-au-Prince is at least five times the amount from a similar study in 1985, suggesting that *overall* charcoal production has increased in virtually every area sampled, including those that show a decline in the *relative* percent of charcoal supplied to Port-au-Prince.
- ***Haitians are not only still meeting their woodfuel needs, they are also producing charcoal at higher volumes, not only from new locations, but also from many of the same historical production regions.*** This suggests that at least part of the charcoal being produced in Haiti is made with biomass resources that are renewable.
- ***Total charcoal sales in Port-au-Prince, Haiti, are approximately US$182 million per year.***

The average cost of a large sack of charcoal was approximately 800 Haitian Gourdes (US$12.42) from July–August 2018. Using these figures, the total estimated value of the charcoal market in Port-au-Prince is US$182 million per year.

- ***At the national level, total charcoal sales across Haiti are an estimated US$392 million per year.*** Using the same values for the price of charcoal as used in the Port-au-Prince calculation, the total value of the national charcoal market is an estimated US$392 million per year.
- ***Based on the calculations of total sales, charcoal represents approximately 5 percent of Haiti's GDP.*** The economic significance of the charcoal industry in Haiti can also be placed in context by comparing it to national GDP. Based on 2017 figures, charcoal represents 4.7 percent of GDP (US$8.408 billion).
- ***Charcoal is over six times more valuable than Haiti's total agriculture-related export market.*** When charcoal's estimated national annual value (US$392,026,140) is compared to 2016 exports of crop and livestock products, charcoal is six times more valuable than all of these exports *combined* (US$62,479,200). Comparing to individual export commodities, charcoal is over 15 times more valuable than the highest-valued export in 2016 (essential oils; US$25.5 million in exports), 30 times more valuable than cacao exports (US$13.2 million), over 40 times more valuable than mango exports (US$9.2 million), and a startling 650 times more valuable than coffee exports (US$611,000).

The results of this study vividly underscore that in Haiti, charcoal is big business.[5] Indeed, based on initial calculations described above, charcoal is the second largest agriculture-related value chain in the country. With a total market size in Port-au-Prince of approximately US$182 million per year and a national market value of approximately US$392 million per year, charcoal is one of Haiti's most important crops. It contributes nearly 5 percent to GDP and has large impacts for employment in rural areas.

[5]A recent study in the Haitian newspaper *Le Nouvelliste* references so-called 'charcoal millionaires'.

The charcoal sector's large—and likely growing—scale stands in stark contrast to the decades of apocalyptic predictions of the rapidly approaching day when a charcoal maker would fell Haiti's last tree. This dynamic sector has continued to defy these forecasts through an intriguing combination of increased geographic reach and the evolution of more sustainable production techniques, relying on sources of renewable biomass.

This study and its innovative charcoal rapid-assessment methodology highlight important new steps in growing efforts to understand the charcoal sector in Haiti. The data presented here shed additional light on charcoal—a poorly understood commodity with multifaceted and far-reaching impacts on Haiti's economy and environment. The persistent stigmatization of charcoal as a dirty, destructive, and illegal fuel source tends to lead to calls for controls on production, or for the replacement of charcoal with other, often more expensive, sources of imported cooking fuels. With these aspects more fully considered, policy makers have the opportunity to capitalize on the economic, environmental, and energy policy opportunities offered by charcoal production in Haiti.

Despite these promising aspects, any such efforts to leverage these economic, environmental and energy opportunities need to equally recognize and mitigate the negative outcomes associated with charcoal production. In particular, the health risks related to the use of charcoal for cooking. This study's narrow focus examining volumes of charcoal transported to Port au Prince, charcoal origin, and historical trends, does not consider the health impacts of the use of charcoal. However, large bodies of ongoing research by the World Health Organization (WHO), Global Alliance for Clean Cookstoves, academic researchers, and other organizations are carefully examining the relationship between health outcomes and cooking fuels/cooking practices. Although much work is still under way to define precisely where biomass stoves and fuels become harmful, it is widely accepted that the use of charcoal for cooking is more hazardous than modern alternatives like Liquid Propane Gas (LPG), natural gas, and electricity. When developing policy related to charcoal, health aspects need to be prioritized and further researched.

Addressing, mitigating, and improving all aspects of the charcoal industry requires additional research and the collation of existing research on: the characteristics of the

charcoal value chain and its many actors; price behaviors and trends; agronomic analyses of current wood energy production techniques by farmers; measures of sustainability and the renewability of charcoal production under different conditions and in different settings; aspects of environmental degradation and/or improvement; cleaner kilns on the production side; safe labor and working conditions on the transportation side; cleaner burning stoves and ventilation systems on the consumption side; and charcoal consumption habits and preferences. Such knowledge, combined with an increasing openness toward engaging in and improving the sector, could provide significant improvements to one of Haiti's largest value chains.

I. Introduction and Background

Introduction

Deforestation and charcoal production in Haiti are widely misunderstood phenomena. This is perhaps nowhere more evident than the misplaced belief that charcoal production is the principal driver of deforestation. It is a well-documented historical fact that Haiti's primordial forests of valuable hardwoods largely vanished as a result of a series of other historical events, highlighted subsequently. In the present era, it is widely believed that some 2 percent of primordial *forests* remain in Haiti, despite that approximately one-third of the surface of Haiti remains covered in *trees* that supply the necessary woody biomass for ongoing charcoal production at the national level.

Misinformation about deforestation and charcoal production in Haiti spread as part of a larger, global phenomenon: the so-called 'woodfuel crisis' of the 1970s and 1980s.[6] This belief drove development planning during those decades and continues to drive popular but misinformed myths around woodfuel use in Haiti and beyond.[7] To illustrate, a widely cited report from 1979 suggested that existing wood supplies in Haiti were enough to meet increasing charcoal demand until around the year 2000, but would ultimately result in an environmental 'apocalypse'.[8] The prediction that wood supplies would be exhausted by 2000 was also supported by a report on trends emerging from the early remote sensing analyses of aerial photographs spanning from 1956 to 1978, in three different locations in Haiti.[9] Forty years later, Haiti is still covered with trees,[10] and Haitians continue to produce large quantities of charcoal to supply their domestic energy needs.

This report directly addresses important and unresolved questions about charcoal production. Since Haitians meet approximately 80 percent of their national energy needs for cooking through firewood and charcoal production,[11] a deeper understanding of current charcoal production in Haiti in the context of a historical perspective is crucial to inform policy decisions for development and government programming related to landscape management, reforestation, tree planting, agroforestry, and agricultural projects in Haiti.

The methodology for data collection was drawn from research spanning nearly half a decade to allow for comparison with previous results. The following section presents a brief review of historical and contemporary knowledge to address widespread misinformation and misconceptions about tree cover, forest cover, and deforestation in Haiti, setting the context for the research questions and methodologies subsequently presented.

[6]Eckholm 1975, 1984.

[7]Leach and Mearns 1988; Mwampamba et al. 2013; Arnold and Dewees 1997; Hansfort and Mertz 2011; Bailis et al. 2017.

[8]Voltaire 1979, 21, 23.

[9]Cohen 1984, v–iv.

[10]Tarter 2016; Tarter et al. 2016.

Background

Haitian Government Legislative and Executive Efforts to Address Deforestation

The first Haitian government efforts to slow the cutting of trees in Haiti were enacted in 1804, the year of Haitian independence, although they were driven more by agricultural production considerations rather than strictly environmental concerns (Bellande 2010, 3). Throughout the 19th century, various Rural Codes provided strictures against the cutting of trees in and around mountain ridges, natural springs, and the banks of rivers (see Bellande 2010 and Bellande 2015 for extensive details)—a strategy reflective of an understanding of linked human and environmental influences.

[11]Charcoal in Haiti is used principally for cooking in urban areas, while wood is used for cooking in rural areas, although wood is used to a much lesser extent in urban bakeries and urban drycleaners.

Such 19th century Haitian government legislation has addressed the ownership, utilization, protection, control, restoration, marketing, and establishment of reserves for natural resources for:[12]

- **Forests:** the Law of February 3, 1926; Law of August 20, 1955; the Rural Code of May 24, 1962, Law No. VIII; Decree of March 18, 1968; Decree of November 21, 1972; Decree of November 20, 1974.
- **Soil:** the Rural Code of May 24, 1962, Law No. V; the Constitution, Article 22; and the Decree of June 16, 1977.
- **Land use and agriculture** (in terms of both state and private land): the Law of July 26, 1927; the Constitution, Article 22; the Rural Code of May 24, 1962, Laws No. IV and V; and the Law of August 11, 1975.[13]

The historical consensus is that while the Haitian government recognized early on the related challenges around proper land and natural resource management—and passed corresponding legislation to address these challenges—they were ultimately not equipped to effectively and equitably enforce these laws at the national level. While the exact percentage of tree or forest cover in Haiti during many of these historical periods is not well established, early historical records provide evidence, and several new studies have provided *current* arboreal coverage estimates.

The Original Forests of Haiti

Haiti was never fully cloaked in forests, largely due to the combined influence of geographical, topographical, and meteorological deterrents—the nation is located on the leeward (i.e., dry), western side of the island of Hispaniola, in the rain shadow of several large mountain ranges that block much of the precipitation carried on the northeastern and Caribbean trade winds.

As a forester completing a survey of the Haiti's timber reserves in 1945 confirmed:

> The appearance of many of the inland smaller mountains and plateaus does not indicate that they ever supported much forest growth, and many rocky hillsides probably never supported heavy timber stands, even though the valleys and ravines are known to have yielded some high-quality timber. A general survey of the country indicates that most of the stories of former vast timber resources of Haiti were probably greatly exaggerated. Even allowing for the difference in rainfall and topography between the North, West, and South coasts, it is still obvious that many of the mountainsides in the central zone and on the West coast were never covered with the heavy mixed vegetation of the Northeast and Southwest, nor with the pine forests of the higher mountain ranges of the Southeast.[14]

Estimates of initial forest cover and land capacity that have considered these natural determinants range from 35 percent (Haitian Ministry of Environment)[15] to 55 percent forest cover (Haitian government's forestry plan of 1975).[16] Stated succinctly, Haiti was probably never more than roughly halfway covered with forests.

The Deforestation of Haiti

Many of the primordial forests of Haiti were felled during the colonial period to establish and support the plantation model of agricultural production that would become the precursor to modern industrialized agriculture. Subsequent tree felling was authorized through contracts established between the fledgling Haitian government and foreign timber concessionaries to pay off a post-independence war indemnity and the new republic's early leaders.[17] Cultural and religious beliefs spared some trees from felling, but both the Catholic and Protestant churches in Haiti later targeted these same species in concerted efforts to destroy them.[18] While the exact percentage of tree or forest cover in Haiti during previous periods is unknown, several new studies have provided current arboreal coverage estimates, which are briefly presented below.

[12]This list is illustrative, not necessarily comprehensive.
[13]USAID 1979, 19–27.

[14]Klein 1945, 5.
[15]World Bank 1982 (pg. 17), citing a 1980 report by the Haitian Government's Département de l'Agriculture des Ressources Naturelles et du Développement Rural DARNDR—now 'Ministère de l'Agriculture des Ressources Naturelles et du Développement Rural (MARNDR).
[16]USAID 1979: 33
[17]See Tarter et al. 2016 for a lengthy history of deforestation in Haiti.
[18]Tarter 2015b.

Current Estimates of Arboreal Coverage in Haiti

A frequently cited figure that repeatedly finds its way into the development literature posits that Haiti is only 2 percent forested. One of the major issues of contention related to this estimate results from the paucity of available data concerning when the figure first surfaced; it was almost assuredly based on extrapolating trends from incomplete data into the future. It is also not clear if the 2 percent figure refers to an estimated percentage of *remaining* forests, and if so, whether or not it is based on the false assumption that 100 percent of Haiti was covered with forests at some point in the past—an assumption that discounts the known environmental determinants of forest cover (geographical, topographical, and meteorological) discussed above. Perhaps the 2 percent figure simply represents an estimate of overall forest land cover at the time of its formulation, although there is no solid empirical evidence that primordial (or primary) forests or forest patches in fact covered 2 percent of the land.

Complicating the issue, how a 'forest' is defined and measured varies significantly by individual, discipline, and institution,[19] casting increasing doubt on the validity of the 2 percent figure and what it actually represents.[20] While the 2 percent estimate probably originated in reference to original, primordial forests, it discounts secondary forests, woodlands, managed woodlots, tree plantations, agroforestry systems, and the many trees found on farms.

Until the recent availability and close examination of high-resolution, remotely sensed (satellite) imagery, researchers estimating arboreal coverage in Haiti relied exclusively on field-site visits or qualitative assessments from aerial flyovers. Six recent research studies summarized here present data based on new satellite data, and reach conclusions contrary to conventionally accepted estimates and the belief that Haiti's landscape is devoid of tree cover:

[19]Lund 2014 lists approximately 1,600 different established definitions for 'forest' and 'forest land'.
[20]Tarter 2016.

The Large Island of La Gônave, Offshore from Port-au-Prince[21]

In 2012, geographers conducted a land-use/land-change analysis of the large island of La Gônave, offshore to the northwest of Port-au-Prince, using two high-resolution Landsat satellite images twenty years apart, from 1990 and 2010. Both photos were selected from late January—the middle of Haiti's dry season—to control for seasonal variability in vegetation and cloud cover. For their classification, researchers considered five different land-cover types that were mutually exclusive and exhaustive of all land types in the area, including separate land category classifications for forests and shrubs. Several complementary and higher resolution satellite photographs were consulted for the accuracy assessment of the image classification, in combination with the analysts' knowledge of the area and a two-month field visit.[22]

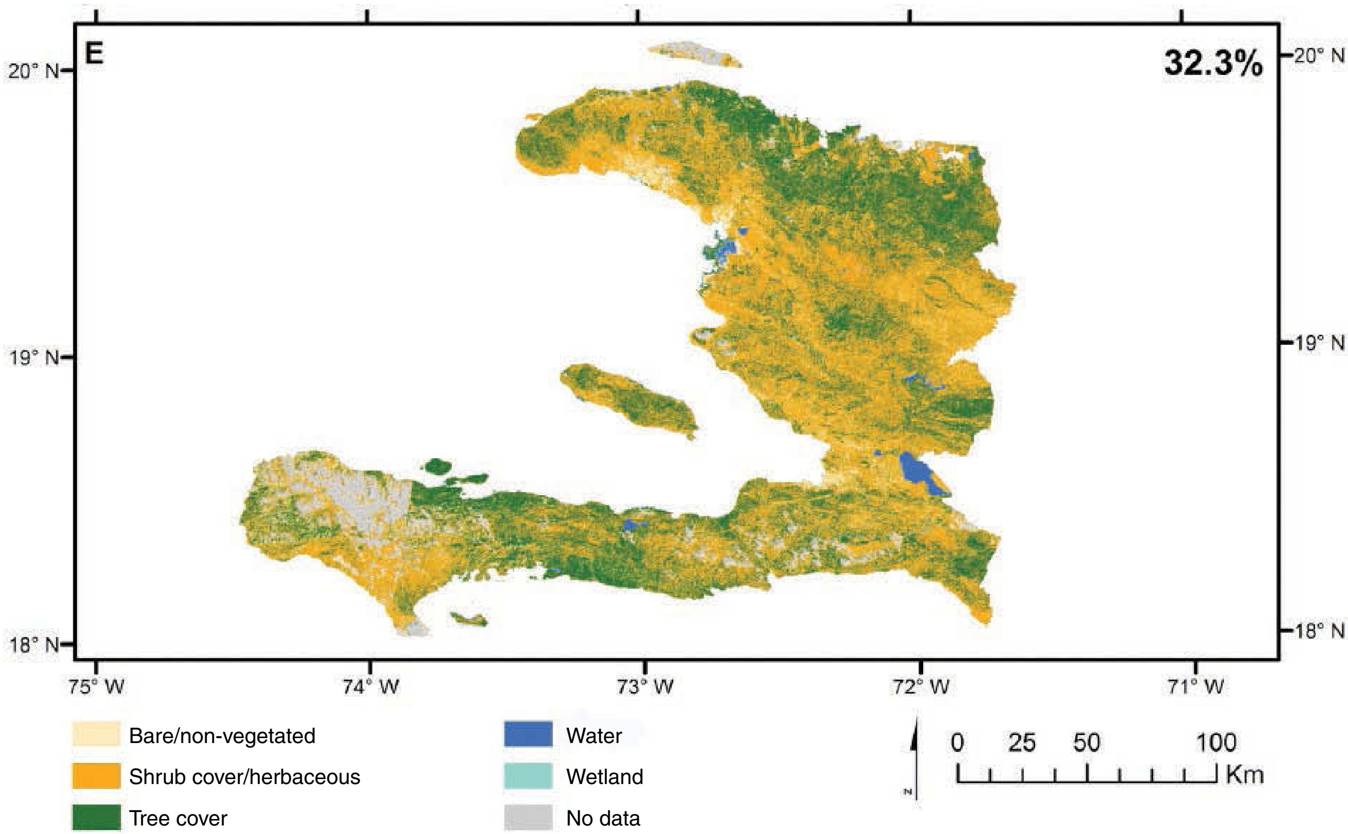
While the overall percentage of the forest land cover decreased over 20 years by 22.7 percent, the majority of 1990 agricultural lands were converted to shrub (45.01%), forest lands (34.23%), and 56.2 percent of the eroded land area in 1990 had been revegetated in 2010. Overall, the shrub coverage in La Gônave increased by 87.4 percent from 1990 to 2010. The entire land surface of La Gônave in 2010 (excluding water and masking the < 2% cloud cover) was 40.4 percent covered with woody shrubs and 46.0 percent covered with forest.

A Nationwide Estimate of Forest and Tree Cover in Haiti[23]

In an analogous study, a geographer, a geologist, and a natural resource management specialist estimated forest cover for the entire country of Haiti. The authors used 2010–2011 Landsat national satellite images of Haiti at

[21]White et al. 2013.
[22]A stratified random sample of validation points to ground-truth their classifications was used. The team averaged 61 verification points for each of the five land-use categories (n = 301 total), locating random geospatial coordinates with GPS units. The random sample strata were 15, 52-meter elevation increments, to look for elevation-based influences (White et al. 2013, 498). The overall accuracy of their 2010 classification was 87%, with a Kappa coefficient of 0.84. The results show that the percent of land area change on La Gônave from 1990 to 2010 for agricultural land, forest/DV, shrub, and barren/eroded land classes, were −39.73%, −22.69%, +87.37%, and −7.04%, respectively (White et al. 2013, 499).
[23]Churches et al. 2014.

Tree cover map produced by Churches et al. 2014



the dry season. After a series of standard renderings and corrections, the authors reclassified their satellite images using FAO's forest class definition, thereby creating a low and high range of percent tree cover.[24] The results of the nationwide analyses showed that in 2010–2011, trees covered 29.4 percent to 32.3 percent of Haiti's land surface,[25] and that shrub areas accounted for 45.7 to 48.6 percent of the land surface.[26] Rather than a thinly dispersed arboreal covering, trees are aggregated in fragments and patches (Churches et al. 2014).

[24]These image classifications were verified through the application of a stratified sample of 1,525 random reference points to higher resolution satellite imagery. Strata were based on the land use distributions from their initial classification (Churches et al. 2014, 209). Their 'tree cover' class had a users' accuracy of 86% and a .81 Kappa statistic, and the overall classification accuracy ranged from 78% reference point counts to 83% class proportions.
[25]Includes 'water', 'wetlands', 'bare/non-vegetated', and 'cloud' categories.
[26]It should be noted that the Churches et al. 2014 study and the White et al. 2013 study used slightly different land-use classifications. Nevertheless, both studies use a single category that operationalizes trees in the same way, and similarly restricts smaller shrubs, and all other land uses. Said succinctly, the tree cover in both studies is similarly classified, though the non-tree cover category varies between studies.

USAID Global Development Lab's GeoCenter Land Cover Analysis of Haiti

In 2016, the GeoCenter of USAID's Global Development Lab undertook a land-cover analysis of Haiti in anticipation of a Notice of Funding Opportunity related to the U.S. Congressional earmark for reforestation efforts in Haiti. The analysis was based on different parameters applied to two different global datasets: (i) Hansen/University of Maryland;[27] and (ii) the World Forests[28] global dataset. Using the second dataset and associated definition of 'forest', USAID estimated forests span 9 percent of Haiti's land area. When applying FAO's standard definition of tree cover[29] for the first dataset, USAID found that 40 percent of Haiti's land area fell under this forest cover definition. Finally, USAID applied custom parameters to the Hansen dataset,[30] suggesting

[27]Hansen et al., 2013.
[28]The BaseVue 2013 World Forests dataset parameters define 'forest cover' as trees higher than three meters in height with a closed canopy of >35%.
[29]Designating 30 m × 30 m units as tree covered if containing vegetation taller than 5 m and greater than 10% canopy cover.
[30]USAID defined 9 intervals of tree cover canopy based on the Hansen 2000 tree cover dataset.

that using the most stringent forest cover definition (>90% canopy cover), forests cover an estimated 11 percent of Haiti's land area, while an estimated 36 percent of Haiti's land area would be considered forest cover when defined by a >50% canopy cover. Stated differently, when USAID applied three different forest definitions to two different global datasets, their analyses yielded present forest cover estimates that ranged from 9 to 36 percent of Haiti's land surface.

A Regional Study of the Greater Antilles[31]

In a broader study of land use changes within the Greater Antilles 2001–2010, researchers observed that 26 Haitian municipalities[32] underwent significant changes to woody vegetation[33] (8 decreased and 18 increased); 36 municipalities underwent significant changes in agriculture/herbaceous cover[34] (25 decreased and 11 increased); and 48 municipalities experienced significant changes in mixed-woody/plantations[35] (9 decreased and 39 increased). Across municipalities of significant change, there was an 8 percent loss of woody vegetation, a 114 percent loss of agriculture/herbaceous, and a 133 percent increase in mixed-woody/plantation. Conversely, in overall land percentages for the entire country, woody vegetation increased from 1 percent, agriculture decreased from 4 percent, and mixed-woody/plantations increased from 4 percent. Municipalities that experienced losses or gains were widely geographically distributed.[36]

An Assessment of Aboveground Biomass in Haiti[37]

A dynamic landscape model[38] was used to simulate changes in land cover if woodfuel demand in Haiti continues unabated. The modeling found that current demand might contribute to moderate levels of ecological degradation, but that "the situation is not as severe as is typically portrayed." Under a 'business-as-usual' scenario, "the simulated regenerative capacity of woody biomass is insufficient to meet Haiti's increasing demand for wood energy and, as a result, between 2017 and 2027 stocks of aboveground (woody) biomass could decline by 4 percent (± 1%), equivalent to an annual loss of 302 kilos/ton (± 29%) of wood." The authors acknowledge that "the input parameters utilized in this preliminary exploration carry large uncertainties," given limits to primary data and model input assumptions.

An Assessment of Biodiversity Linked to Remaining 'Primary Forest' in Haiti[39]

In late 2018, a report was released indicating that 'primary forest' in Haiti has declined from an amount equal to 4.40 percent of the total land area in 1988, to an amount representing 0.32 percent of the land area in 2016.[40] The research uses a definition of 'primary forest' that assumes a "stringent 70 percent threshold [for tree canopy] and then eliminates cases of major regrowth (secondary growth) by following 30-m pixels back in time to make sure to always represent forested areas."[41] Here the definition of 'primary forest' is restricted to those areas with a tree canopy cover equal to or greater than 70 percent, unchanged over the last 33 years (excluding areas of significant arboreal regrowth), and only on plots of land larger than 0.5 hectares. Although certain aspects of the methodology of this study need to be examined further,[42] the study identifies important primary forest areas that represent some of the hotspots of remaining and highly sensitive animal (and plant) biodiversity.

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31 Álvarez-Berríos et al. 2013.

32 Sections communales.

33 Woody vegetation was defined as trees and shrubs with >80% cover.

34 '*Agriculture/herbaceous vegetation* was annual crops, grasslands, and pastures with >80% cover' (Álvarez-Berríos et al. 2013, 86).

35 "*Mixed-woody/plantations* was woody vegetation with a 20% to 80% cover, including agriculture/herbaceous vegetation or bare soil as background, as well as all forms of plantations and perennial agriculture" (Álvarez-Berríos et al. 2013, 86).

36 This points to the wide decentralization of charcoal production in Haiti.

37 Ghilardi et al. 2018.

38 Modeling Fuelwood Sustainability Scenarios (MoFuSS).

39 Hedges, Blair, S., Warren B. Cohen, Joel Timyan, and Zhiqiang Yang. 2018. Haiti's biodiversity threatened by nearly complete loss of primary forest. Proceedings of the National Academies of the Sciences. Online/pre-print version accessed Nov. 1. https://doi.org/10.1073/pnas.1809753115.

40 Hedges et al. 2018, 1.

41 Ibid., brackets authors, parentheses original.

42 Two methodological questions should be raised: (1) The study's generalization of results from the few areas of remaining 'primary forests' to the national level is based on the assumption that at one point in the past the entire land surface of Haiti was covered with such forests, whereas, as cited, the combined influences of geography, topography, and meteorology suggests that the natural capacity for forest cover in Haiti ranges from 35–55%; and (2) do all nine categories from Holdridge's life zones—an ecological classificatory system developed in, and for, Haiti, but now applied as a globally recognized standard (Holdridge 1947, 1967)—meet this new definition of 'primary forest'? For example, 'Subtropical Dry Forest' (19% of Haiti's land) and 'Subtropical Thorn Woodland' (less than 1%) may not meet the 70% canopy threshold. Other serious concerns about the methodology remain but are beyond the scope of this report.

Charcoal sold by the bucket in a local market

Traditional charcoal stoves

These findings, highlighting differences in how forests are conceptualized and measured, and collectively presenting overwhelming data contrary to popular depictions of charcoal and deforestation narratives about Haiti, induce the research questions posed in this report.

The Historical Production of Charcoal in Haiti

Charcoal production in Haiti commenced around the 1920s.[43, 44] Prior to that time, given the large rural population distribution, most Haitians met their domestic energy needs through firewood, which could be procured in rural areas, a task mostly relegated to children and women.[45]

The rise of charcoal production in Haiti in the 1920s correlates with increasing urbanization that occurred not only in Haiti, and particularly in Port-au-Prince, but also as regional and global phenomena. Increased charcoal production was also facilitated by the emphasis in the 1920s[46] to rehabilitate existing and build new transportation infrastructure, including roads, railways, and maritime wharfs. Increased urbanization and population densities called for more agricultural clearing and charcoal production.

Research from other analogous locations throughout the world has debunked many myths surrounding woodfuels, especially the conclusion that charcoal production is the primary driver of deforestation.[47] Although there has been lengthy debate over whether charcoal production or agricultural clearing is the principal driver of deforestation in Haiti,[48] the widely cited historical figure suggesting that only 2 percent of Haiti's primordial forests remain is disassociated from either argument. Charcoal in Haiti is largely produced from trees, not forests, trees found in woodlands, woodlots, agroforestry systems, and on farms.

The Use of Non-Charcoal Wood in Haiti

The present study examines charcoal use precisely because it is the principle use of wood in Haiti, primarily for cooking.

[43]Tarter 2015a; Tarter et al. 2016.

[44]Haitian agronomist, researcher, and author Alex Bellande has recently uncovered the earliest known reference to charcoal production in Haiti: a report of charcoal entering the capital by railway in 1909 from the Haitian newspaper *Le Nouvelliste,* listing a total of approximately 375 metric tons for six months during 1909 (Bellande, personal communication, 10/16/2018).

[45]See Annex 6 for a discussion on the gendered division of labor and the differential gender effects on health related to the product, transport, marketing, and consumption of charcoal in Haiti.

[46]1919–1934.

[47]Leach and Mearns 1988; Mwampamba et al. 2013; Arnold and Dewees 1997; Hansfort and Mertz 2011; Bailis et al. 2017.

[48]Stevenson 1989.

Although rural dwellers use wood or a mix of charcoal and wood for cooking, urban and peri-urban dwellers use almost exclusively charcoal. The use of charcoal in urban areas relates to the economics of moving wood versus charcoal (charcoal is lighter, more compact) and it burns less smoky than wood, making it more comfortable for densely populated areas. In Haiti, food cooked with charcoal is also a cultural preference, related to custom and stated preferences for the flavor of food cooked with charcoal, and for this reason, charcoal is the preferred fuel for most Haitians. The choice to use fuelwood for cooking in rural areas is related to cost—it is generally free to cut wood in rural areas, whereas charcoal carries a cost.

Beyond uses for cooking, the literature occasionally references the ongoing use of wood in urban businesses such as dry cleaners and bakeries; however, these are few (around an estimated 100 across the country) and result in a negligible amount of wood compared to the demands from charcoal production. Other uses of wood in Haiti include furniture, doors, beds, coffins, and construction scaffolding. However, the demand for these products is limited (scaffolding polls are reused between jobs, and furniture and other carpentry works are imported).

The use of and demand for charcoal in Haiti dwarfs that of wood, and for this reason this research focuses exclusively on the movement of charcoal toward the principle urban market of Port-au-Prince.

The Historical Supply of Charcoal to Port-au-Prince

The first historical areas of large-scale charcoal production in Haiti occurred east of the capital city of Port-au-Prince, and later shifted offshore to the nearby island of La Gonâve, as areas in closer proximity to the capital started producing charcoal. Then charcoal production moved into the northwest peninsula, and later swung to the more remote southern peninsula, and to a lesser extent into Haiti's Central Plateau area.[49] Charcoal production designated for the capital, the largest consumer to date, commenced in areas close and accessible to Port-au-Prince before shifting toward geographically remote areas.

By around 1980, estimates suggested that only 5 percent of charcoal consumed in Port-au-Prince came from the area east of the capital, where large-scale production had historically commenced.[50] Likewise, only 5 percent of charcoal consumed in Port-au-Prince came from central Haiti; 10 percent came from the large offshore island of La Gônave; 50 percent originated from the northwestern peninsula; and 30 percent from the southern peninsula. Voltaire predicted charcoal production would eventually shift from the rapidly depleting areas of La Gônave and the Northwest to the more wooded areas of the Central Plateau and Grand Anse.[51] Table 1 displays these and subsequent estimations of varied regional contributions to the charcoal consumed in the capital city of Port-au-Prince.

The first comprehensive, robust survey on the production and consumption of charcoal in Haiti[52] was administered some six years after Voltaire's report and predictions. According to the study, by 1985 the northwestern area of Haiti was supplying 34.2 percent of charcoal consumed in the capital; the large off-shore island of La Gônave supplied 7 percent; the Central Plateau area supplied 12.7 percent; the southeast supplied 10.3 percent; an area in the center of the southern peninsula provided 28.1 percent; and an area toward the end of the southern peninsula supplied 7.7 percent (see Table 1).

Contemporary Charcoal Production in Port-au-Prince

According to the Haitian government's National Institute for Statistics and Information (IHSI), Port-au-Prince has an estimated population of 2,618,894,[53] which is over seven times the population of the second largest city of Gonaïves (356,324) and nearly ten times the population of the third largest city of Cap-Haïtien (274,404). As such, the capital remains the largest consumer of charcoal in the country, and the logical location from which to sample and extrapolate to produce an estimate of annual charcoal consumption for the capital and the urban population of the country.

49 Smucker 1981; Conway 1979; Voltaire 1979.

50 Voltaire 1979.

51 Ibid.

52 Grosenick and McGowan 1986.

53 IHSI 2015.

TABLE 1: Regional Contributions to Annual Charcoal Consumption in Port-au-Prince

Year	Main production areas	Est. % contribution	Source
1930s	East of Port-au-Prince; Island of La Gonave; Northwestern peninsula	~100%	Smucker 1981; Conway 1979
1979	East of Port-au-Prince	~5%	Voltaire 1979
	Island of La Gonave	~10%	
	Northwest	~50%	
	Central Plateau	~5%	
	Southern peninsula	~30%	
1985	East of Port-au-Prince	~0%	Grosenick and McGowan 1986
	Island of La Gonave	~7%	
	Northwest	~34.2%	
	Center (Croix-des-Bouquets, Hinche, St. Marc)	~12.7%	
	Southern peninsula (Center of southern peninsula ~28.1%; tip of southern peninsula/ Grand Anse ~7.7%)	~35.8%	
	Southeast (Jacmel and Thiotte)	~10.3%	
1990	Grand Anse	~13	ESMAP 1991
	Island of La Gonâve	~5	
	Northwest	~21	
	Central (Central Plateau and east of Port-au-Prince)	~13	
	South	~2	
	Southeast	~3	
	West	~26	
	Artibonite	~13	
	North	~4	
2005–2007	The southern peninsula (Grand Anse, Belle-Anse, Aquin, the south coast); the Northwest; and the Central Plateau (Maïssade, Thomonde, Thomassique, Pignon, Cerca-Cavajal, Hinche, Mirebalais, Boucan Carr., Saut d'Eau, and Lascahobas)	~100%	ESMAP 2007

II. Research Questions and Methodology

Research Questions

As a general, historical, and widely observed trend, charcoal in Haiti is produced rurally and transported for consumption to urban areas, in contrast to wood, which is largely consumed in rural areas.[54] Since the majority of charcoal produced in Haiti is geared toward consumption in the capital city of Port-au-Prince, the following, overarching questions guided this research design:

- (**R1**) How much charcoal is consumed annually in the capital city of Port-au-Prince?
- (**R2**) Which geographical regions produce the charcoal consumed in the capital?
- (**R3**) How do these production areas variably supply charcoal to the capital?
- (**R4**) In what ways have these trends changed over the last 40 years?
- (**R5**) What percentage of charcoal consumed in the capital is originating from the bordering Dominican Republic?

Methodology

Principal Method

The principal method of this study mirrored previous estimation methods—to count charcoal transport vehicles (trucks) and vessels (boats) entering the capital city of Port-au-Prince and/or passing through important roads or crossroads *en route* to the capital.

Teams of three enumerators were positioned at roadside stations and maritime wharfs alongside 23 carefully identified locations throughout the country. The enumerators took shifts manning the stations for 24 hours a day, over three different sampling periods. Enumerators not only tallied every single passing charcoal vehicle or incoming charcoal vessel, they also recorded the date and time of each observation, permitting hourly and daily analyses.

Methodological Similarities and Differences from Previous Studies

The methodology presented below is based largely on an earlier study of charcoal consumption in Port-au-Prince, produced by researchers from the University of Maine, working in conjunction with the decade-long Agroforestry Outreach Project (AOP).[55] This methodological approach was loosely replicated in various forms in several subsequent studies (see Table 2).

By modeling the methodology on aspects of these earlier studies, it is possible to provide both cross-sectional (2017) and longitudinal (diachronic changes over almost four decades) estimates of nationwide charcoal production and consumption trends in Haiti.

Other aspects of the methodology are independent of these earlier studies, in order to address new research questions pertinent to current production and consumption patterns in Haiti.

Timeframe of the Fieldwork Scoping[56]

During a preliminary scoping phase (2016–2017) the research team conducted visits and undertook contextual interviews to identify the important charcoal depot (wholesaler) locations in Port-au-Prince. The team examined storage points accessible by roads and sea, and in warehouses and wharfs. The interviews and observations allowed the team to develop a typology of charcoal transportation vehicles (trucks and boats). In addition, the research team visited locations throughout the country to identify the places along roads and at key intersections where enumeration stations would be placed during the survey phase.

[54]Exceptions include wood used in bakeries and drycleaners, although these are negligible amounts in comparison to the amount of wood that is transformed into charcoal.

[55]Grosenick and McGowan 1986.

[56]See Annex 1.

TABLE 2: Differences between Previous Charcoal Study Approaches

Study	Principal method	Sampling period(s)	Locations	Time period
Grosenick and McGowan 1986	Stopping vehicles at checkpoints and counting charcoal bags	Three one-week periods, although due to political unrest, only two weeks were utilized: • July 1985; and • May 1986	Police checkpoints on two major highways that controlled all traffic into the capital from the North, Southeast, and Southwest.	24 hours
			High traffic periods on lesser roads and on important maritime wharfs: • Avant Poste de Police (police station) at Cazeau (north and southeast); • Avant Poste de Police in Brochette/ Carrefour (southwest); • Intersection of Rue Huc and Delmas (major entry location for charcoal on donkeys); • Djoumbala on Rue Freres (major entry location for charcoal on donkeys); • Cité Soleil wharf (maritime arrivals); • Martissant/La Rochelle wharf (maritime arrivals); and • Jérémie wharf (maritime arrivals).	High traffic periods
ESMAP 1991	Counts of the number of charcoal shipments entering Port-au-Prince	One week in February 1990; Averaged with counts from the first trimester of 1989	• Gressier; • Wharf Martissant; • Wharf Cite Soleil; • Wharf Jérémie; • Wharf Lamantin; • Mariani; • Croix-des-Bouquets; and • Croix-des-Mission.	Not clear
ESMAP 2007	Assessing arrivals: number of bags, transportation means used, source of charcoal	One week in the capital; Buttressed with supplementary surveys conducted over an undetermined amount of time	• Carrefour Shada (northern entrance); • Rond Point de la Croix des Bouquets Police Station (Central Plateau and border zone); • Gressier (southern entrance); • Cité Soleil wharf; • Jérémy wharf; • La Rochelle wharf; • Mariani; and • Croix-des-Bouquets market.	Partial daytime coverage (areas listed to the left) Partial nighttime coverage (Carrefour Shada, Croix des Bouquets, and Gressier, only)

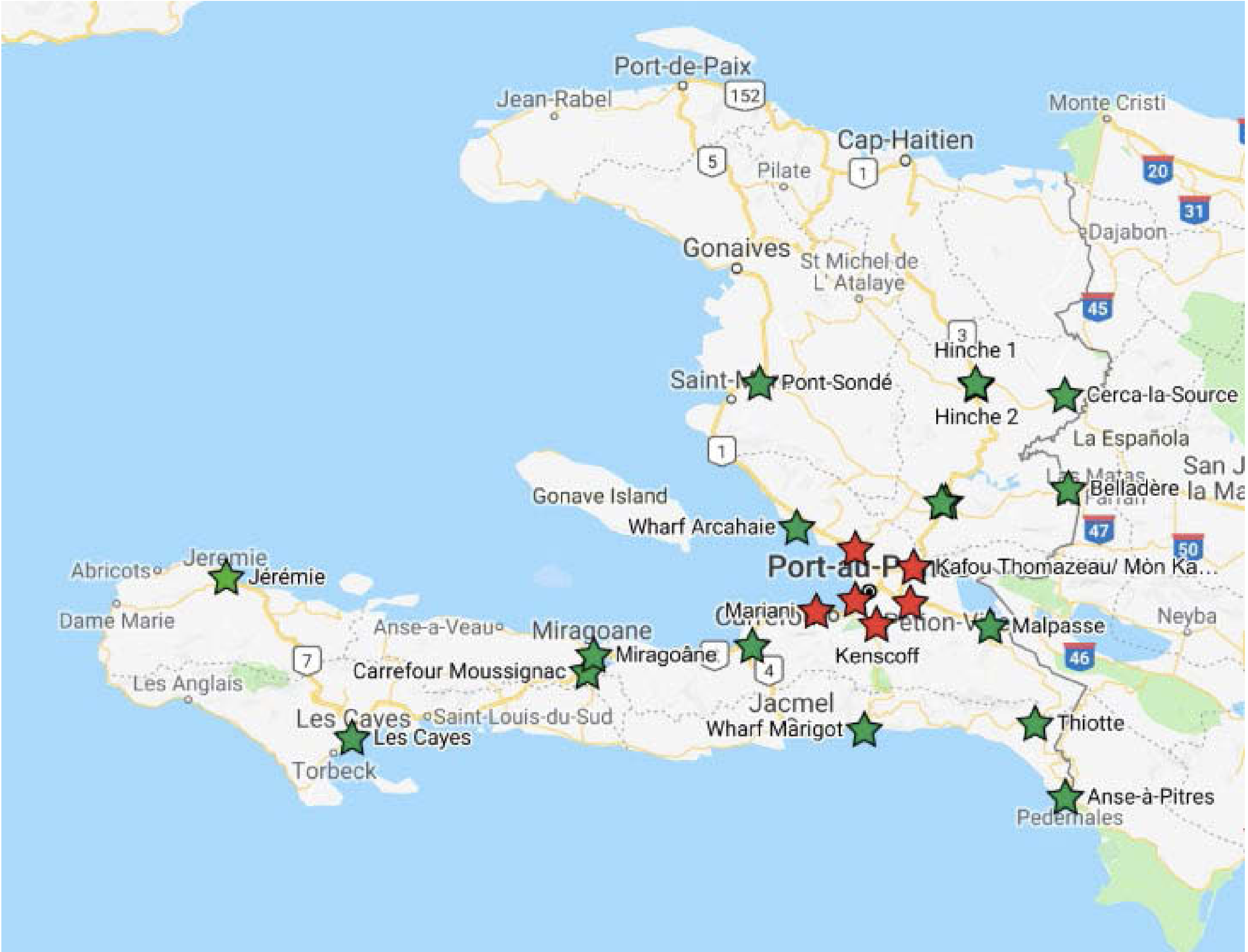
While the studies outlined in Table 2 vary in sampling strategy, duration, and robustness, they represent the best and only data available. This study takes Earl's (1976) and Voltaire's estimates (1979) as baselines, although they do not use methodologies similar to those presented in Table 2. All comparisons made in the analyses and concluding chapter of this report recognize these limits and control a series of variables to increase comparability between and across these early reports.

Sampling

Spatial Sampling: Core and Periphery

Figure 1 identifies the location of 23 different charcoal vehicle/vessel enumeration stations located on major roads, at important intersections, and at maritime wharfs across most of Haiti. Enumeration stations farthest from the capital or at

FIGURE 1: Geographical Dispersion of 23 Enumeration Sites



Note: The red points represent the six core stations (Croix-des-Bouquets, Kafou Thomazeau/Mòn Kabrit, Kenscoff, Mariani, Titanyen, Wharf Jérémie). The green points represent the periphery points.[57] Hinche 1 and 2 overlap due to their close proximity.

the intersection of two major routes provide 'periphery' counts that further disaggregate the location of charcoal production, while those located around the capital are referred to as 'core' stations. More precisely:

- The **core** accounts for the six final enumeration stations that all trucks and boats must pass through to enter the metropolitan area of Port-au-Prince.[58] The core data do not suffer from double-counting that may occur in the periphery, whereby different enumeration stations count the same truck on the same day *en route* into the capital. Instead, core counts represent the final amounts of charcoal entering the metropolitan area of Port-au-Prince and are used to make estimations of the consumption level of charcoal in the capital, and later to make extrapolations to the entire country based on a *tons-to-population* ratio and associated economic national estimates.
- The **periphery** stations are all other enumeration stations outside of the Port-au-Prince area. Many of the periphery stations are located at intersections, and thus control for charcoal flows headed in the direction toward the capital from more than one location.

[57]See the entire list of the enumeration stations in Table 5.
[58]The metropolitan population of Port-au-Prince encompasses all areas included in our 'core' (the communes of Port-au-Prince, Delmas, Cite Soleil, Tabarre, Carrefour, and Pétion-Ville).

All subsequent results are noted as *core* or *periphery* results. Final counts presented in the subsequent analysis are based on the six 'core' stations in order to avoid double-counting of trucks. The periphery stations allow for the determination of approximate geographical origins of production for charcoal supplied to Port-au-Prince.

Temporal Sampling: The Annual Calendar for Charcoal Production[59]

Previous research demonstrated seasonal fluctuations in annual charcoal production in Haiti. The scoping phase of this research found similar results—interview respondents confirmed that there are low and high seasons of charcoal production.

High seasons of charcoal production correspond to periods when households anticipate higher than normal financial expenditures. According to the interviews conducted during this research and more generally on Haitian households' expenditures, school-associated costs are one of the most frequently reported costs for which the rural population must make provision. The two periods during which primary school enrollment fees must be paid include the first semester of the school year (August/September), and the second semester (December/January).[60, 61]

Trees are also harvested for charcoal during increased periods of drought, when crop failure is widespread. In the case of crop failure, charcoal production intensifies when it becomes apparent that seasonal rains are insufficient to produce a marketable crop, although droughts are often experienced differentially by region. Charcoal production lulls during the rainy seasons and during periods when farmers and their families are occupied with the preparation of fields, planting, weeding, harvesting, processing, and marketing of agricultural food crops.

Despite these difficulties in determining exact seasonal fluctuations in charcoal production on an annual basis, three intervals of time are generally considered as peak charcoal production periods across rural Haiti: (1) August/September; (2) December/January; and (3) May/June. It is also generally believed that the first range is the highest production period, but regional differences should not be discounted. The remaining intervals of time throughout the year may be considered as lower production periods. These seasonal differences provide for six months of peak charcoal production, and six months of low production in a typical year.

Timeline of Data Collection[62]

The research protocol was initially designed for data collection during two sampling periods of one week each:

(i) One week in a high-production season, August 2017; and
(ii) One week in a low-production season, October 2017.

The aim of this design was to collect data from weekly periods that could be applied to associated low and high charcoal production seasons throughout the year, producing an annual estimate that considers seasonal production fluctuations.

However, due to logistical issues[63] during the first sampling period, a third sampling period of 72 hours was added in December 2017—another peak period—to make up for hours missed during the peak period of August 2017 (see Table 3).[64]

Reconstruction of a Peak and a Low Period

The sample data for the peak charcoal production season were divided between two periods (1 and 3, see Table 3). In order to construct a complete peak week for comparison to the complete week from low production season, sampling periods weeks 1 and 3 were combined. When there were observations from both peak periods, the means of tons and the mean number of trucks were used. When there were data from only one period, values from the observed period were imputed into the new peak season week. This methodology is described in further detail in Section III Results.

[59] 'High' and 'peak' are used interchangeably as synonyms across the report.
[60] This also corresponds to the pre-Christmas expenditure period.
[61] The 2017 school year began on September 4, as decreed by the Ministry of Education's (MENFP) academic calendar. However, it is common in rural Haiti that children do not return to school on the start date. Many families instead delay until they are able to gather the money to pay for school fees, books, and uniforms. (MENFP Ministère de l'Education Nationale et de la Formation Professionnelle.)

[62] See Annex 1 for more details.
[63] An error was made by the firm contracted to collect the data. All enumerators were mistakenly sent home 17 hours early during the first sampling period. The firm mitigated the mistake by resampling a few days during the following peak season (sampling period 3 in Table 3).
[64] See Annex 2 for further details about the logistical organization on the field.

TABLE 3: Description of the Three Sampling Periods

Day	Su	M	T	W	Th	F	Sa	Total hours
Period 1 (8/26/17, 7 pm– 9/1/17, 7 pm)	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	19 hrs (12 am–7 pm)	*5 hrs (7 pm–12 am)	144
Period 2 (10/23/17, 7 am–10/30/17, 7 am)	24 hrs	*24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	24 hrs	168
Period 3 (12/15/17, 7 am–12/18/17, 7 am)	24 hrs	7 hrs (12 am[67]–7 am)	No data	No data	No data	*17 hrs (7 am–12 am)	24 hrs	72
Total hours	**72**	**55**	**48**	**48**	**48**	**60**	**53**	**384**

* = Sampling period start time

TABLE 4: Conversion of Categorical Counts to Metric Ton Averages

Truck Size	Truck carrying capacity (full capacity with large sacks)	Truck weight range (metric tons)		
		Low-end range	Midrange	High-end range
Small truck	25–50	0.75	1.125	1.5
Medium truck	100–200	3	4.5	6
Large truck	300–400	9	10.5	12

Data Standardization

Standardizing Vehicle Classifications

Roadside enumerations were based on a tripartite typology of transportation vehicles (small, medium, or large trucks); enumerators counted and classified different-sized charcoal-carrying vehicles. During Phase I, a series of 'carrying capacity ranges' were established for each of these three truck categories, based on trucks at full capacity with large bags.[65]

The estimated average weight of a large charcoal bag was initially established by repeatedly weighing large bags (n = 72 bags) at four different locations (two wharfs and two charcoal depots) throughout Port-au-Prince, with an average of 41.93 kilograms per large charcoal bag.[66] Previous researchers also varied as to the weight they ascribed to a large bag of charcoal. Since the most relevant early studies used a 30 kg average for a large charcoal bag,[67] and other important studies reported counts of different-sized bags but also reported weight totals in tons,[68] for the sake of comparability across time, this study uses a 30 kg estimate for a large sack of charcoal. Given that the average of the 72 bags of charcoal weighed was 41.93 kgs, the 30 kg number used in the present calculations is a conservative estimate. Table 4 outlines the carrying capacities and associated ranges of metric tons ascribed to enumerator counts of small, medium, and large trucks.

The subsequent data are analyzed as: (1) counts of the different categories in the tripartite vehicle typology; and (2) total weight based on the average (midrange) of the metric ton ranges for each type of truck, as displayed in Table 4.

Distinction among Vessels and Vehicles

The three wharfs that were sampled also function as *de facto* charcoal depots, with some bags of charcoal stacked high and sitting for indeterminate periods of time. Those enumerators stationed at maritime wharfs were instructed, trained, and

[65] A.M. denotes midnight; P.M denotes noon.

[66] The range of the weight of the 72 large bags was wide, from 20 kg large bags to 65 kg large bags. Since weights varied so much, the mode of all the bags was also not a viable option. In Haiti charcoal bags vary in weight tremendously by the type of wood that produced the charcoal, the moisture content of the charcoal, the sizes of the charcoal pieces, the occasional addition of rocks, and slight variations in the sizes of bags themselves.

[67] Earl 1976; Voltaire 1979; Smucker 1981; Grosenick and McGowan 1986.

[68] Stevenson 1989; ESMAP 1991; ESMAP 2007.

Large truck

Medium truck

Small truck

equipped to count not only charcoal vessels entering the wharfs, but also to record trucks departing the wharfs, which had come to fill their beds with charcoal.

In the final analysis, wharf counts were based on those vehicles departing wharfs with beds full of charcoal, rather than on incoming boats. This ensured that charcoal *en route* to the capital was counted during the respective sampling periods, rather than counting charcoal that may be stored at wharfs for undetermined durations of time, that could have extended the amounts headed for the capital during sampling periods.

Enumerators also noted the origins of boats entering the wharfs, and the quantities of charcoal such boats carried, in order to estimate percentages that reflected different origins of charcoal. This effort was similar to those enumerators station at intersections, noting the specific direction each vehicle originated from. However, all respondents at Wharf Marigot noted that charcoal arrived from the southeast, all respondents at Wharf Jérémie (in Port-au-Prince) reported maritime arrivals came from Grand Anse, and all respondents at Wharf Arcahaie reported charcoal incoming from the island of La Gonâve.[69]

Wharf Archahaie from La Gonâve

[69]This is only unusual in the case of Wharf Arcahaie, where the historical literature indicated that charcoal offloaded at the wharf is separated by that coming from the island of La Gonâve and that originating in the northwest. It appears that the advent of better transportation has changed this historical trend.

III. Results

Descriptive Statistics

Enumerators made a total of 10,436[70] observations of small, medium, or large trucks during the 384 hours of data collection across three different sampling periods, in the 23 enumeration stations, (see Table 5). These observations consisted of 3,790 trucks entering Port-au-Prince (core) and 6646 trucks heading toward the capital (periphery).[71]

The data collection and classification were potentially susceptible to different sources of errors. In order to mitigate any potential errors, several measures were adopted (see Annex 3 for more details).

Two locations had no observations: *Belladère* and *Anse-à-Pitres*. The *Belladère* enumeration station was at an intersection controlling two routes of entry near the border with the Dominican Republic. *Anse-à-Pitres* was controlling for charcoal entering Haiti at the southern-most land point along the Haiti-Dominican Republic border. In subsequent figures, the two stations with no observations will not be displayed.[72]

In addition, some other enumeration stations were outliers, failing to generate substantial observations. This was the case for the *Cerca-la-Source* enumeration station, where only 31 observations were made at an intersection controlling for two routes of entry along the central border with the Dominican Republic. There were also only six total observations from the *Kenscoff* enumeration station in Pétion-Ville, which controlled for charcoal entering the capital from the large and wooded mountain ranges due south that tower above Port-au-Prince.

TABLE 5: Total Number of Observations by Location and Size[73]

Enumeration station	Truck size			Grand total
	L	M	S	
Anse-à-Pitres	0	0	0	0
Belladère	0	0	0	0
Carrefour Dufort	631	391	413	1,435
Carrefour Mariani	530	338	315	1,183
Carrefour Moussignac	586	154	442	1,182
Les Cayes	347	163	374	884
Cerca-La-Source	14	13	4	31
Croix-des-Bouquets	293	161	179	633
Hinche 1	87	28	69	184
Hinche 2	112	36	91	239
Jérémie	120	28	45	193
Mòn Kabrit/Thomazeau	319	120	669	1,108
Kenscoff	1	0	5	6
Malpassee	102	38	50	190
Miragoâne	515	206	455	1,176
Mirbalais_1	235	45	131	411
Mirbalais_2	54	26	31	111
Pont-Sondé	112	60	193	365
Thiotte	87	8	5	100
Titanyen	163	144	246	553
Wharf Archahaie	44	28	8	80
Wharf Jérémie	5	22	280	307
Wharf Marigot	2	22	41	65
Grand total	**4,359**	**2,031**	**4,046**	**10,436**

[70]These figures represent raw data, before any standardization of the dataset occurred.
[71]In the periphery stations some observations are repeats (i.e., the same truck recorded at more than one enumeration station, *en route* to the capital).
[72]Enumerators were still posted at these stations for the full 384 hours of observation across all three sampling periods.

[73]These figures represent raw data, before any standardization of the dataset occurred.

Differences between the Three Sampling Periods

Comparison of All Three Sampling Periods Based on One Shared Day

Sunday is the only complete (24-hour) day when data were collected across all three sampling periods. Figure 2 shows a comparison of the total metric tons circulating in the periphery, and passing into the core on Sunday, for all three sampling periods combined. From Figure 2, sampling period 3 appears to have the highest flows of metric tons into the core; this trend is repeated in the periphery but does not account for double-counting along the same route, or for charcoal that was offloaded prior to entering Port-au-Prince.

Establishing seasonal differences in charcoal production based on only one day can create certain caveats in the data interpretation, including statistical overgeneralization of results considering daily variations within a weekly period. To mitigate this challenge, data are compared in several ways to highlight the real variation between sampling periods. Figure 2 compares the means of tons per hour passing through enumeration stations during the 24 overlapping hours between the three sample periods 1, 2, and 3 in the periphery and in the core enumeration points.

It appears that more charcoal is circulating in the periphery than in the core. Generally speaking, this is true, as urban areas outside of Port-au-Prince consume charcoal as well, and not all charcoal passing through periphery stations also passed into the core. However, the totals from the periphery were also subject to double-counting of the same trucks by different enumeration stations along the same road.

Comparison of All Sampling Periods Based on Total Shared Hours

This section compares the 47-hour period shared across all three sampling periods, as shown in Table 6.

TABLE 6: Description of the 47 Hours Overlap across All Sample Periods

Weekday	Time period	Number of hours
Sunday	All	24
Monday	(12 am to 6 am)	7
Friday	(7 am to 6 pm)	12
Saturday	(7 pm to 11 pm)	4
Total		47

FIGURE 2: Total Charcoal Production by Periphery and Core for All Periods (in metric tons, Sunday—24 hours)

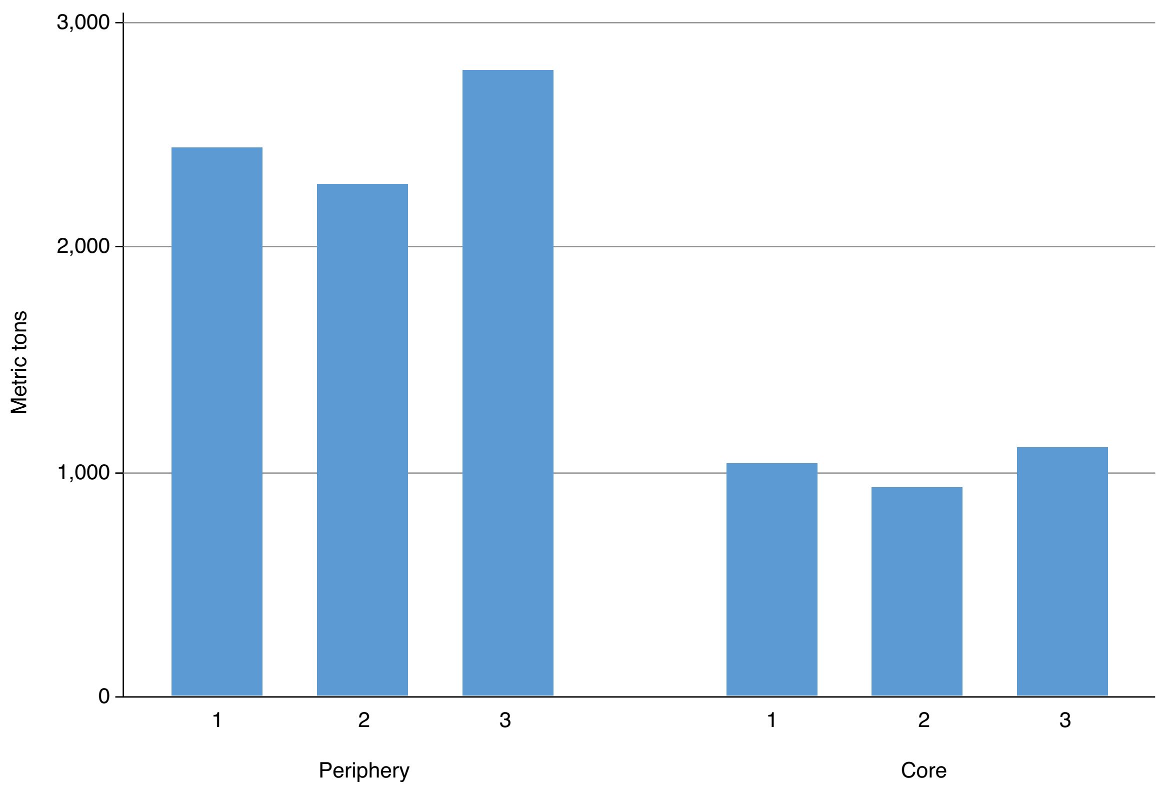
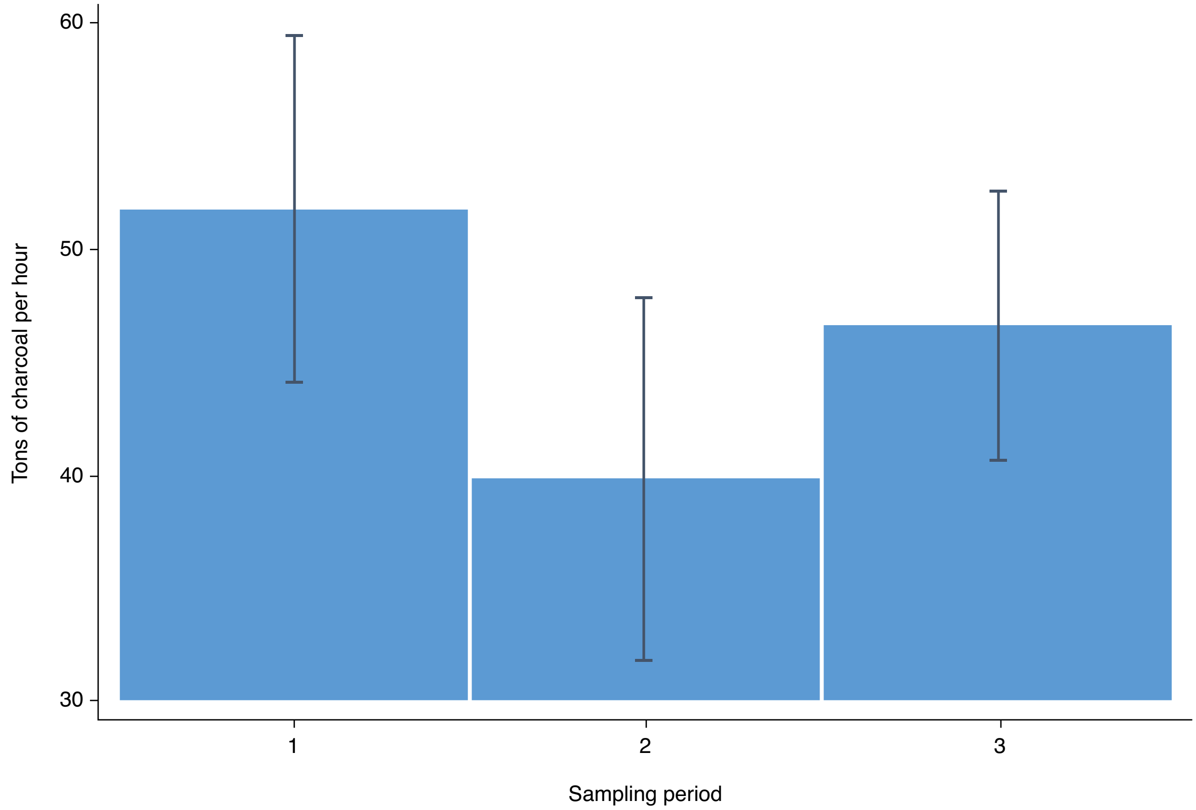


FIGURE 3: Average Tons per Hour across the Three Sampling Periods on the 47-hour Overlap



When these temporal overlaps between all sampling periods are added together, we can compare metric ton flows of charcoal into Port-au-Prince across all three sampling periods, based on a combined 47 shared hours (see Figure 3).

Figure 3 shows that on average sampling periods 1 and 3 both register more overall metric tons of charcoal entering the core of Port-au-Prince than sampling period 2. Given that daily hours of sunlight vary by season, Figure 4 shows only daylight hours in order to control for this seasonal difference. It displays the average tons per hour across the three sampling periods' daylight overlapping hours (7 am–7 pm). Figure 4 shows that that quantity of charcoal transported during daylight hours (7 am–7 pm) is higher per hour in December than in August. In other words, the average total tons of charcoal transported per daylight hour is higher in the wintertime. This is logical given that, during the month of August there are more hours of daylight, permitting trucks transporting charcoal to travel over a greater number of daylight hours than in the winter.

Reconstruction of the Peak Week

Despite small observable variations, the difference between sampling period 1 and 2 is not statically significant. Figure 2, Figure 3, and Figure 4 demonstrate what the qualitative interviews suggested: Period samples 1 and 3 (peak season) have on average more metric tons entering Port-au-Prince than sample period 2 (low season).

As described in Section II, due to 17 hours of missing data during sample period 1, sample periods 1 and 3 are merged to recreate a full week of peak. When there are observations from both periods, tons of charcoal and number of trucks are averaged across the two periods. Where data from only one period was observed, values from the observed period are imputed to the unique peak week construction.

Figure 5 reproduces Figure 3, and Figure 6 reproduces Figure 4, but in each case with the newly reconstructed peak week. These statistical robustness checks confirm the hypothesis of low and high charcoal production season. Figures 5 and 6 demonstrate that the average tons per hour for the peak weeks are significantly higher than in the low weeks.

Robustness Check on Number of Trucks

Figure 7 compares the mean number of trucks of each size per hour for the low week and for the reconstructed peak

FIGURE 4: Average Tons per Hour across the Three Sampling Periods [7 am, 7 pm]

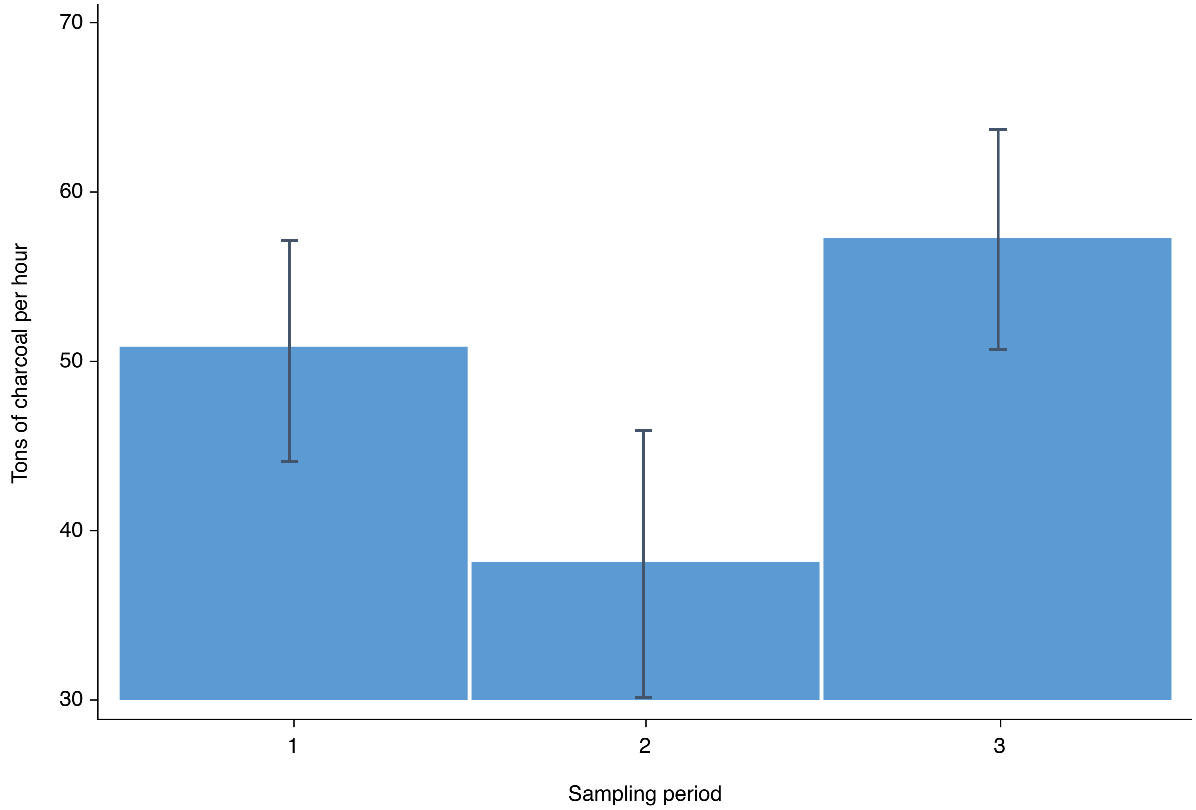


FIGURE 5: Average Tons per Hour of Peak (reconstructed) vs. Low Weeks

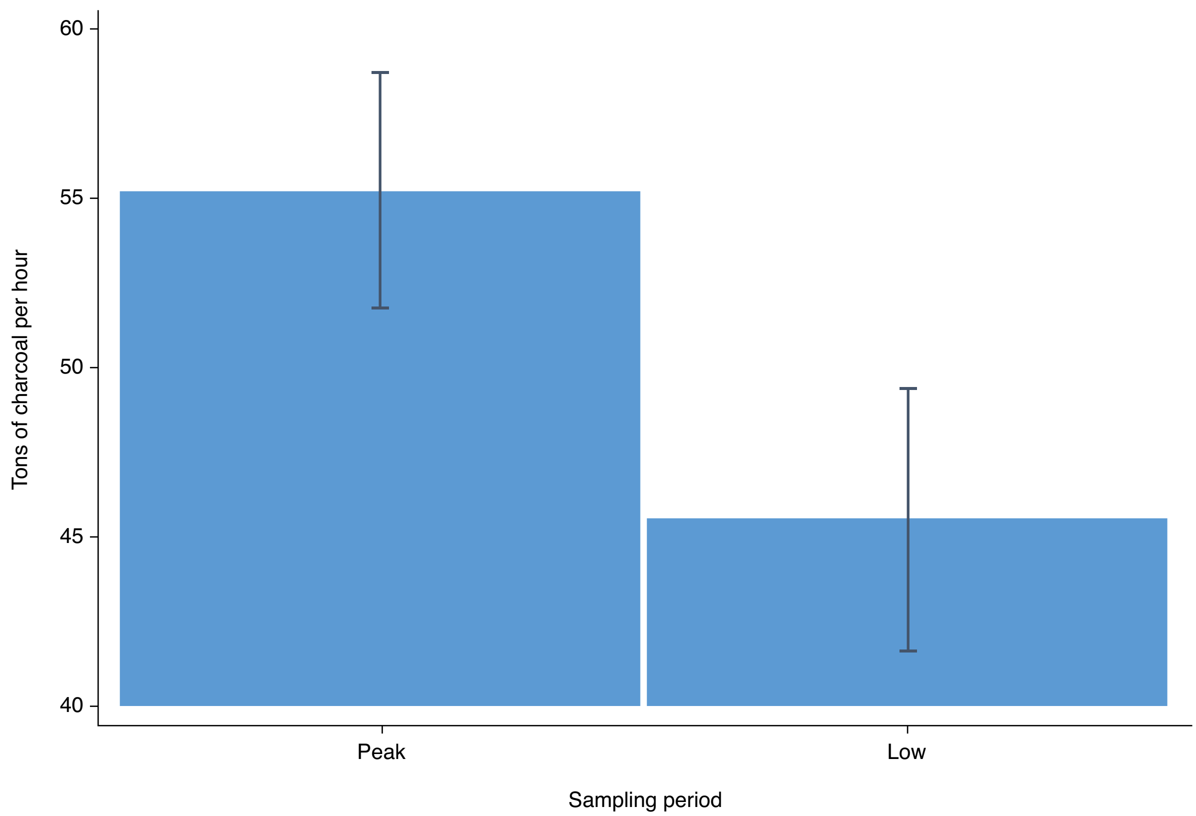


FIGURE 6: Average Tons per Hour of Peak (reconstructed) vs. Low Weeks [7 am–7 pm]

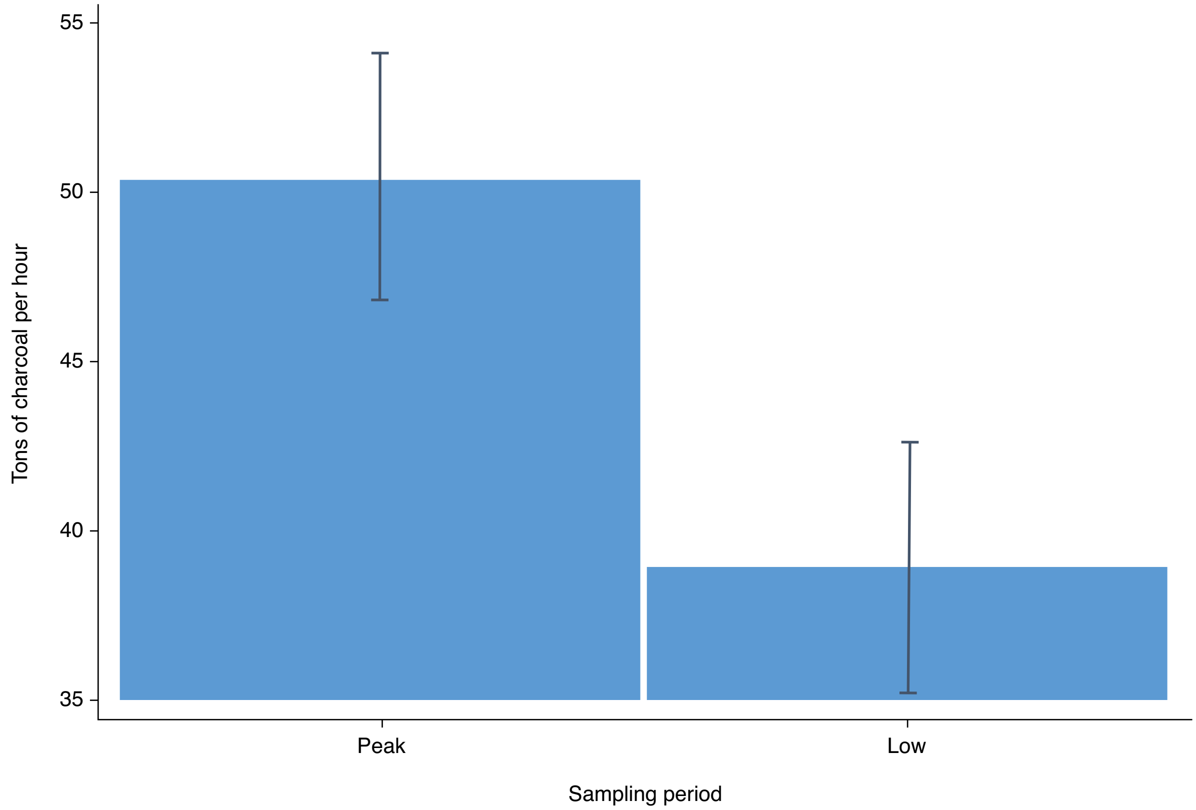
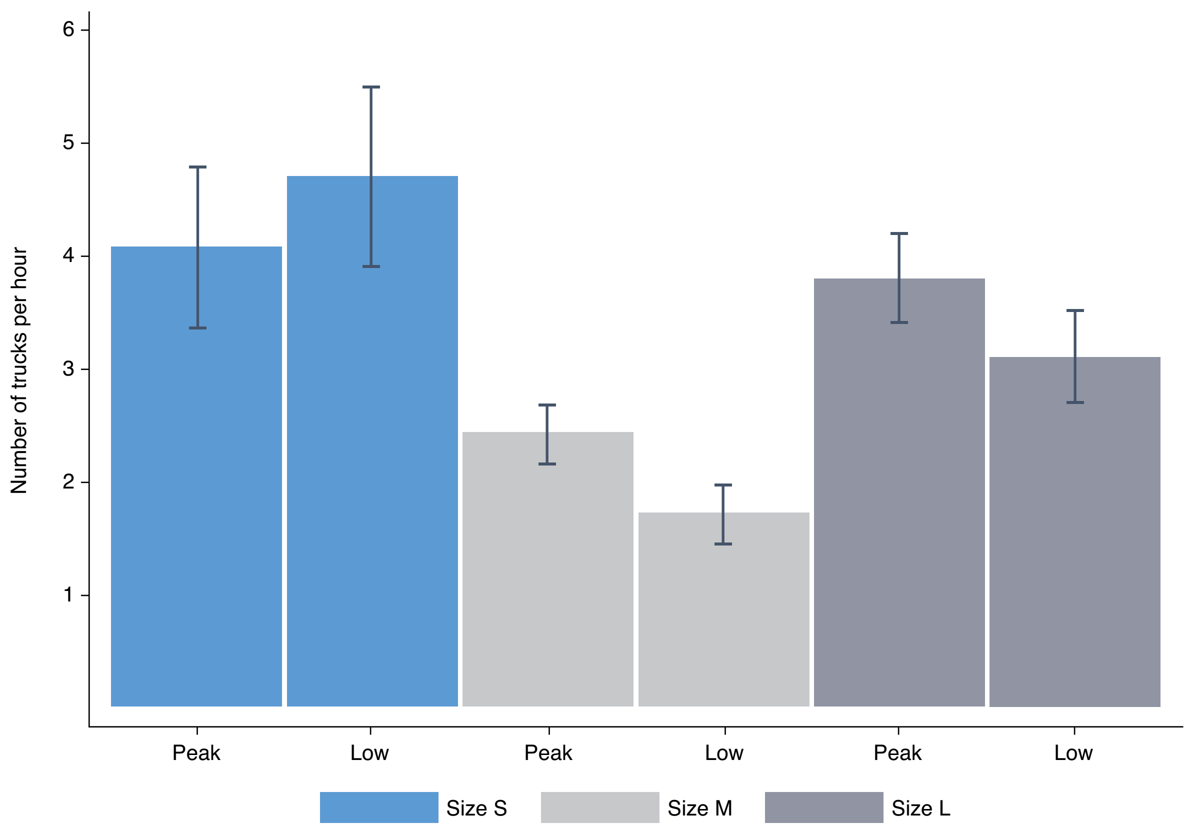


FIGURE 7: Average Number of Trucks by Size for Low and Peak (new) Weeks



week. It is clear that these two periods have different trends. As expected, the low season has on average more small trucks, and the peak season records on average more medium and large trucks of charcoal. In the low season, charcoal continues to be transported, but with smaller trucks than in the peak season, because the overall quantities to be transported are smaller. In the high season, larger trucks are used to transport the larger amounts of charcoal.

Variation within Days and across the Week

There are differences between the days of the week within a given sampling period, both in terms of the volumes of different types of vehicles used to transport charcoal, and the overall flows of metric tons into the core of Port-au-Prince.

Figure 8 and Figure 9 show the distribution of charcoal flows over the course of the week for peak and low seasons. As expected, the low season displays overall lower levels of charcoal flows. The peak and low seasons demonstrate the same trend, except on Thursday and Friday.

In Figure 9 it is clear that Thursday and Friday are the days when peak and low flows are the most different. Monday is the only day when we observe more charcoal being transported in low season than in peak season. The highest volume of charcoal entering Port-au-Prince during the peak season is Thursday and during the low season is Monday. In order to have a clearer idea of how these flows vary per day and per hour, Figure 10 examines the distribution of charcoal flows by hour for both peak and low seasons.

Figure 10 shows some trend reversal, with larger volumes of charcoal transported between 7 pm–midnight during the low season. This trend reverts during the peak season, when volumes are higher between midnight and 7 am.

Finally, the hourly pattern of the tons of transported charcoal day-by-day was examined to provide the most complete picture of the quantities entering Port-au-Prince (Annex 4). By analyzing the hourly flows day-by-day, the data confirm that there is a

FIGURE 8: Charcoal Flows over Time: Peak vs. Low Period in a Week's Time

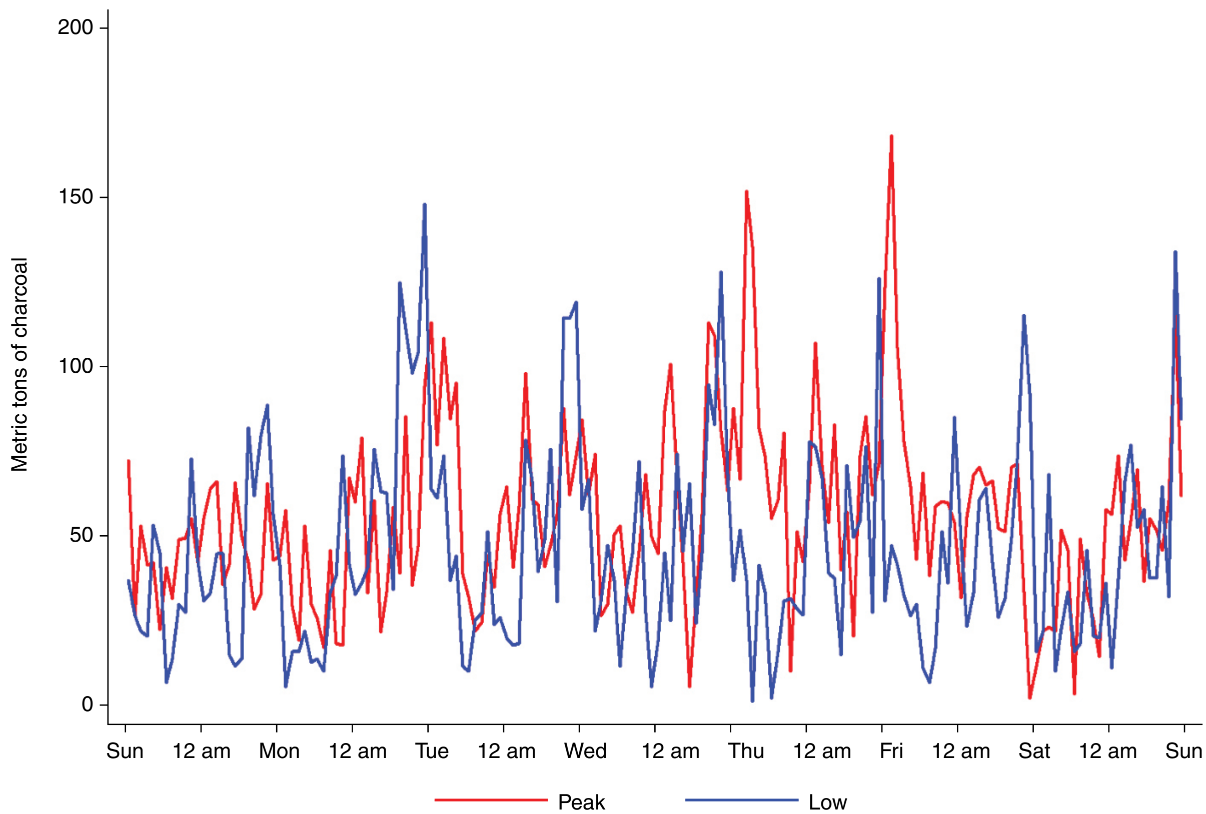


FIGURE 9: Distribution of Charcoal Flows by Day

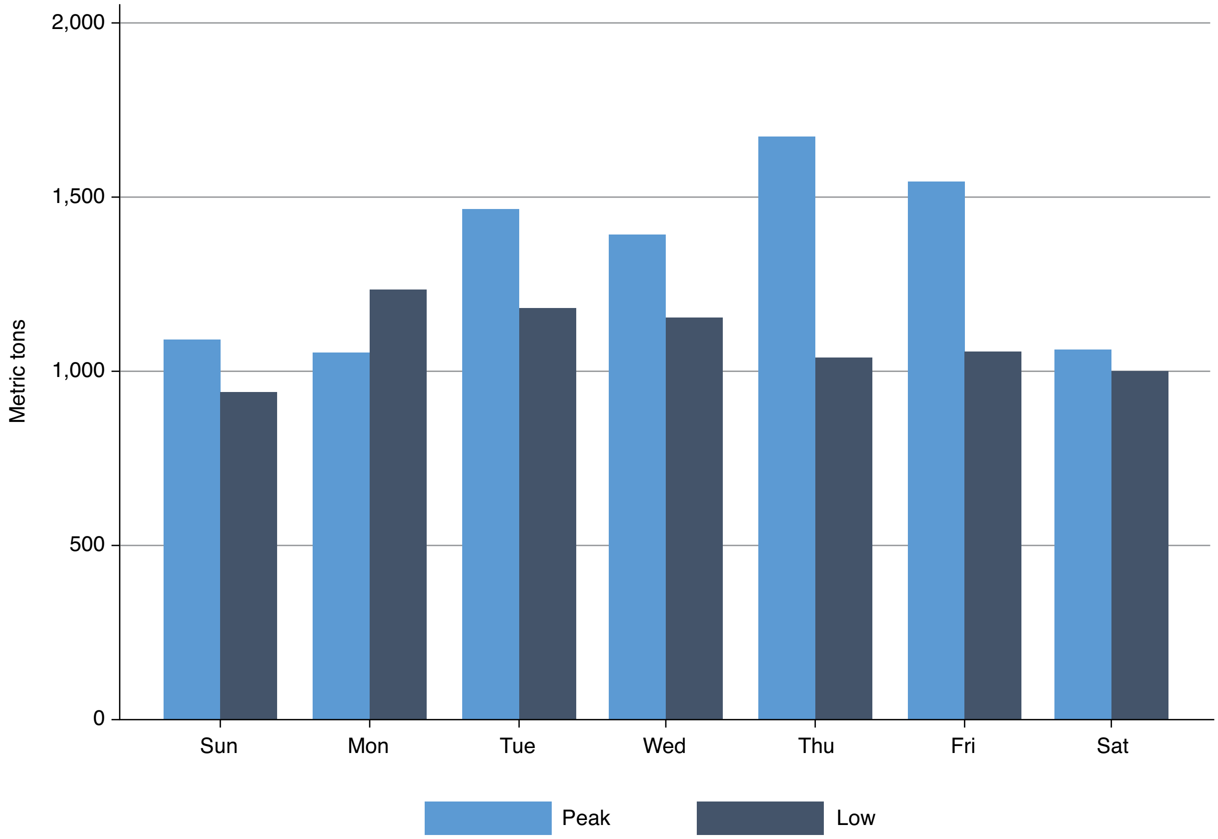
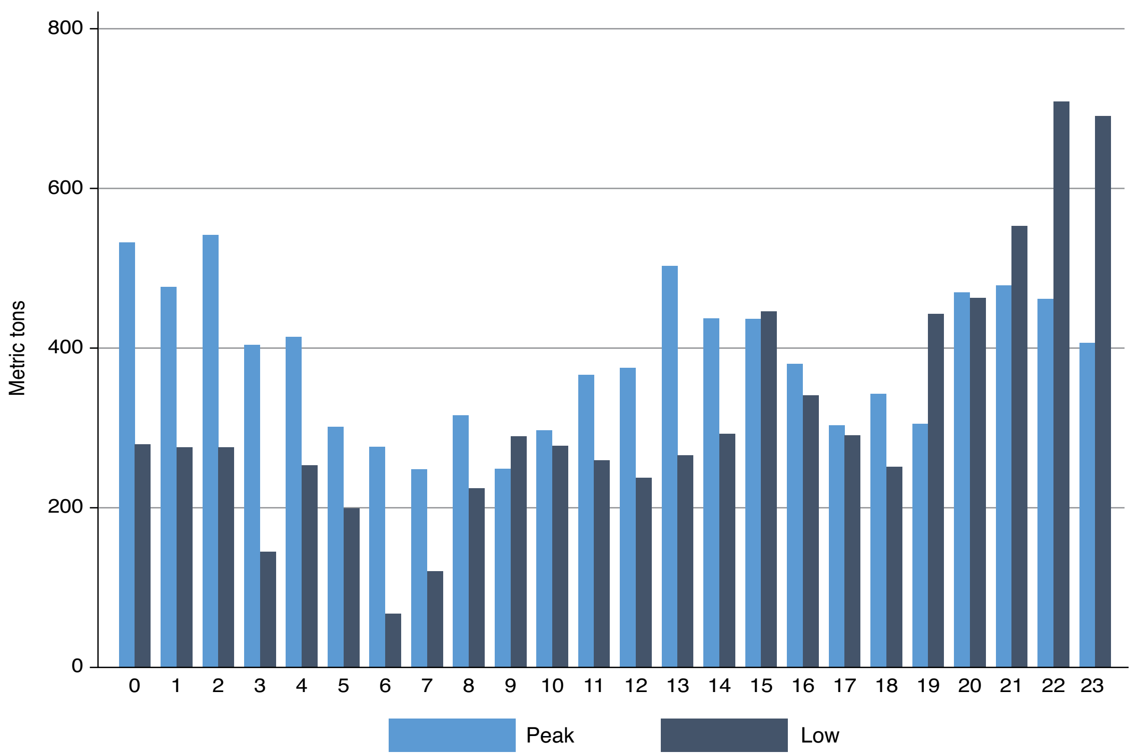


FIGURE 10: Distribution of Charcoal Flows by Hour



daily change at about 7 pm, occasionally shorty after 7 pm, and another change in flows at midnight on almost every day.

Regional Differences

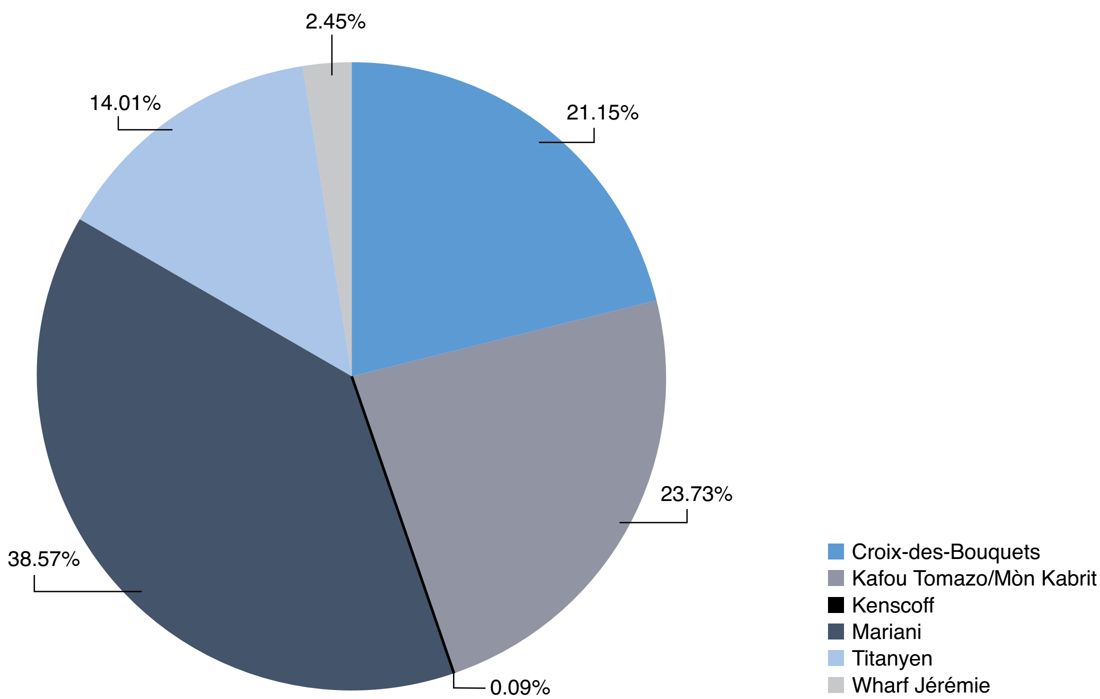
Figure 11 displays the different *regional* contributions of charcoal entering Port-au-Prince, as percentages of the total amount entering the capital during combined peak and low periods.

Approximately 40 percent of charcoal consumed in Port-au-Prince originates from the southern peninsula.[74] The second highest contributor of charcoal consumed in the capital initially appears to come from the Central Plateau area, captured at the enumeration station of Kafou Tomazo/Mon Kabrit and contributing 23.73 percent of the total charcoal flow in the Port-au-Prince. However, since this station is situated at an intersection, the true amount originating from the Central Plateau area, when subtracting the portion from Rue Tomazo (with charcoal originating east of Port-au-Prince), is 20.34 percent, placing it in third place as a regional contributor.

Thus, the second largest flow of charcoal enters the capital from the east, enumerated at the Croix-des-Bouquets station (21.15%) joined with the percent from Rue Tomazo (3.39%) to represent a total of 24.54 percent of the charcoal consumed in Port-au-Prince. Likewise, 14.01 percent of charcoal entering the capital originates from the north, as observed by the Titanyen enumeration station. A small amount (2.45%) enters the capital at Wharf Jérémie (attributed to the southern peninsula), while the negligible remainder, so small it fails to show in the image, enters from the mountain ranges directly south of Port-au-Prince measured at the Kenscoff enumeration station.

Before turning to regional trends, the influence of the farthest out (most remote) periphery stations and smaller feeder roads to the national highways and departmental routes are discussed.

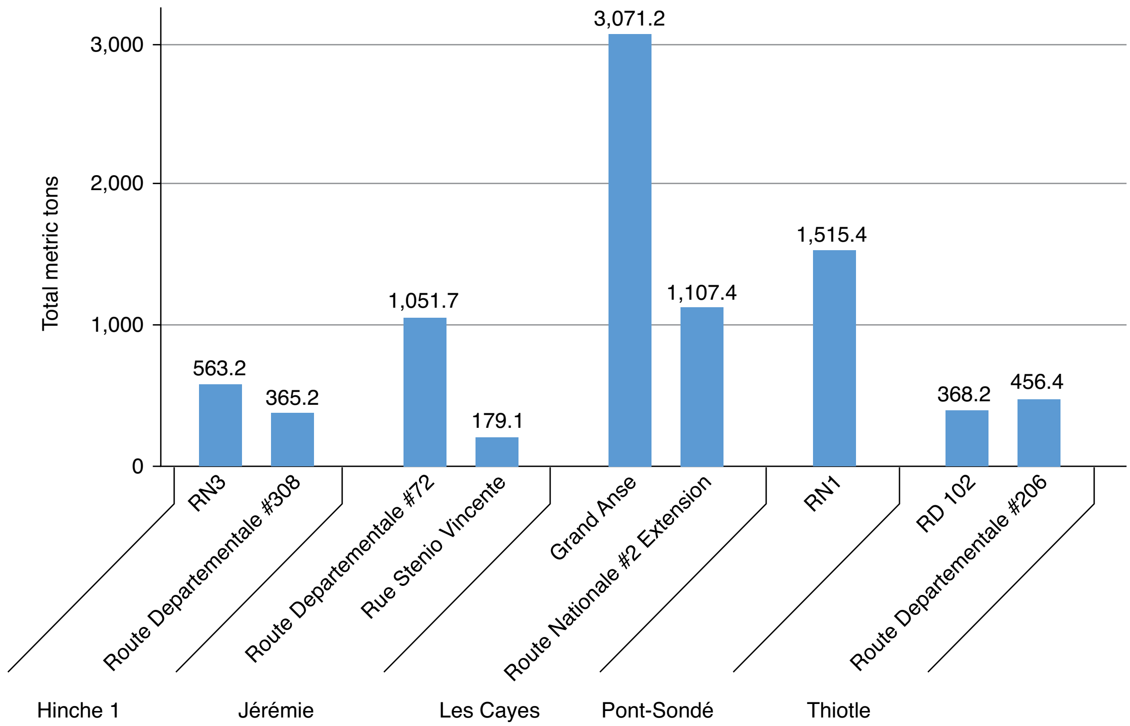
FIGURE 11: Charcoal Entering the Core of Port-au-Prince[75]



[74]This total considers the sum of the Mariani enumeration station and Wharf Jérémie. While Wharf Jérémie is indeed a core station due to its location within the capital, it can be added to the Mariani station due to the origin of this charcoal (Jérémie is located in the southern peninsula).

[75]The charcoal origination from Kenscoff is so small, it fails to appear in Figure 11.

FIGURE 12: Total Metric Tons in the Four Most Remote Periphery Stations



The Effects of the Farthest Periphery Stations and Feeder Roads

Farthest Out Periphery Stations

Figure 12 displays the total metric tons that passed through the four most remote (periphery) enumeration stations during data collection.

The charcoal noted passing through these most remote enumeration stations alone yielded a total amount equivalent to approximately half of the charcoal entering the entire capital from all directions during that same period of time.

The core capital counts show that only a portion of this amount actually entered the capital, illustrating not only the extent to which charcoal production has become decentralized at the national level, but also how much charcoal is now consumed in urban areas located outside of Port-au-Prince.

Feeder Roads

Figure 13 displays only the small feeder roads and departmental roads—analogous to tributaries of a river that join the national highway system in Haiti—where the charcoal enumerated represents an amount equivalent to over one-third (34%) of the charcoal consumed in Port-au-Prince during the same time. Inevitably, much of this charcoal was later counted again on major national highways closer to the capital, but no double-counting occurred on the feeder roads themselves.

Taken together, the influence of feeder roads and the most remote enumeration stations demonstrate just how much charcoal production has become decentralized in Haiti, how a large portion of charcoal is produced in areas very remote from the capital, and how only a portion of this charcoal actually makes its way into Port-au-Prince.

The Southern Peninsula

As noted in Figure 11, approximately 40 percent of the charcoal entering Port-au-Prince originates somewhere along the southern peninsula, west of the Mariani enumeration station or entering from Wharf Jérémie.

Figure 14 displays the total metric tons that passed through each of the enumeration stations of the southern peninsula before reaching the core Port-au-Prince station of Mariani.[76]

[76]Note that enumeration stations in this image are *not* arranged left-to-right in a manner that reflects their actual position (east-to-west) on the road.

FIGURE 13: Metric Tons Produced by Feeder Roads

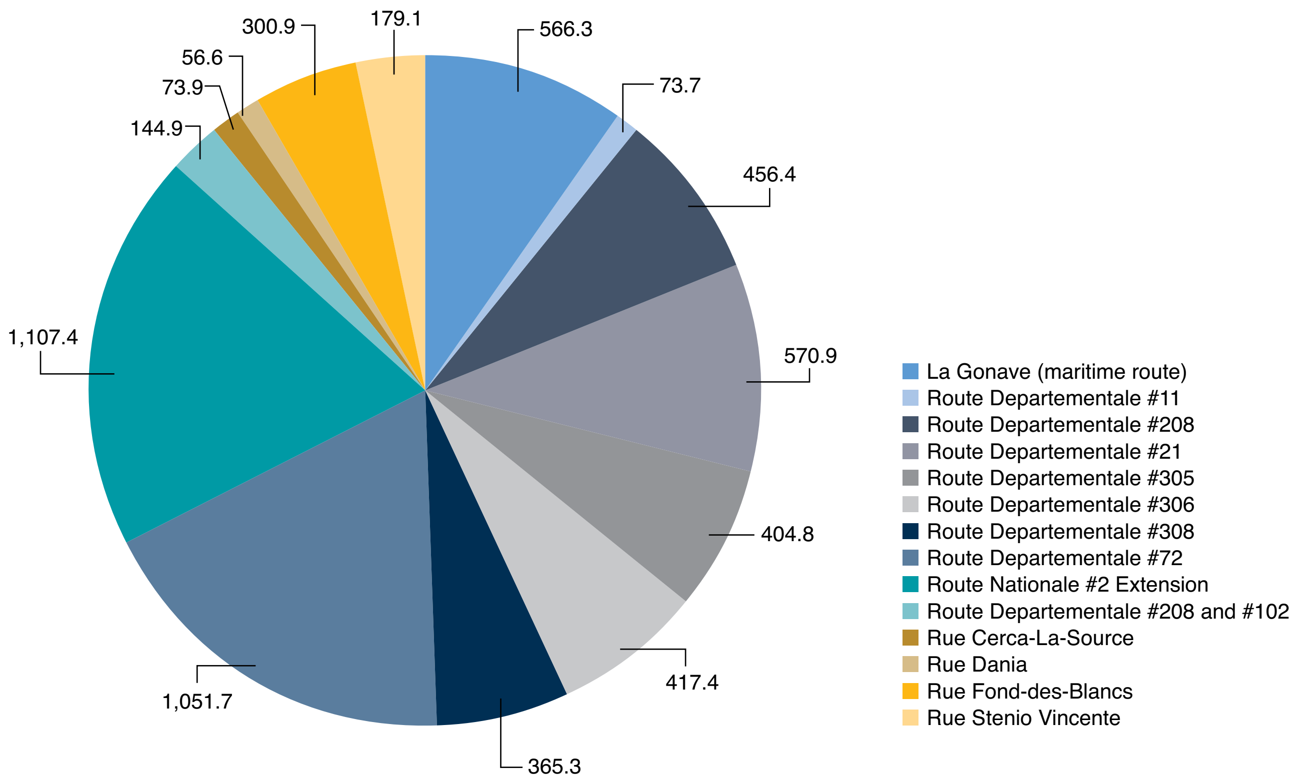
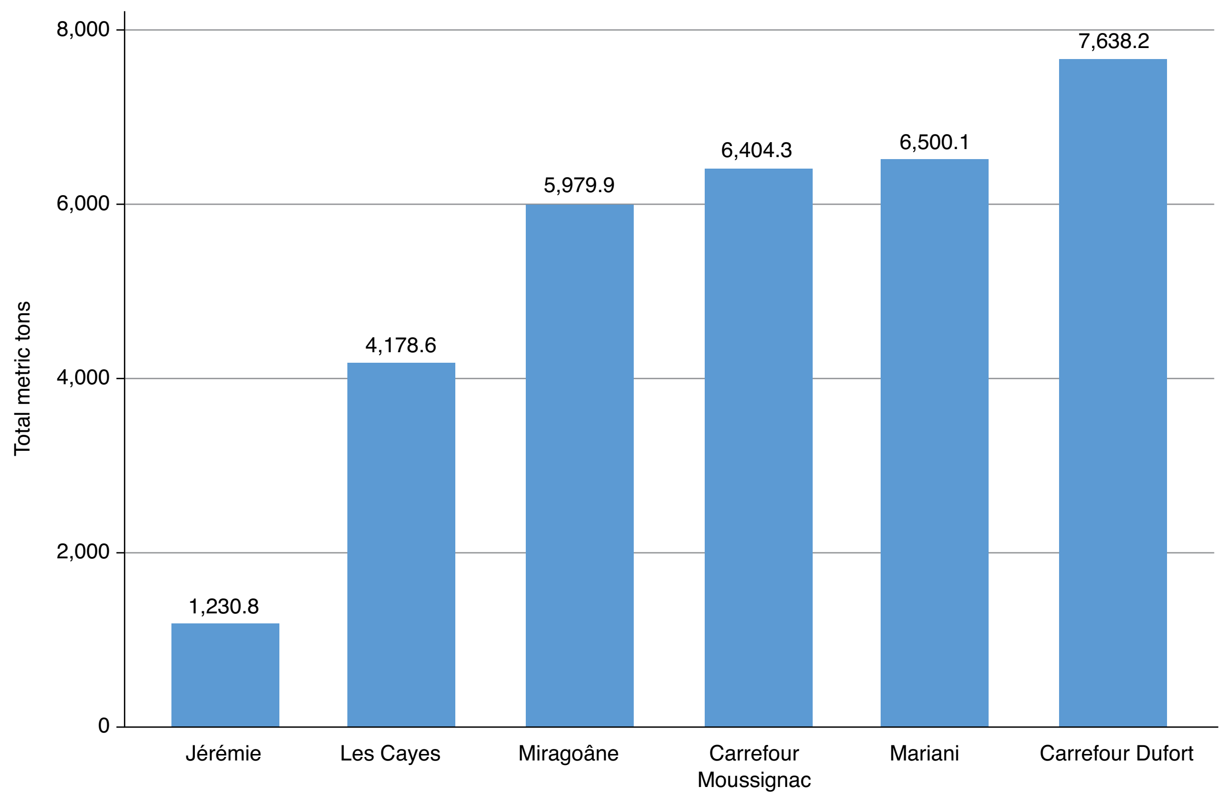


FIGURE 14: Metric Tons Passing Through Enumeration Stations of the Southern Peninsula



What is immediately clear is that there is not an increasing progression of charcoal toward Port-au-Prince. There *are* notable increases (Jérémie to Les Cayes; and Miragoâne to Carrefour Dufort) and notable declines (Carrefour Moussignac to Miragoâne; and Carrefour Dufort to Mariani,) of total charcoal flows between stations when considering a west-to-east trajectory toward the capital. The most significant decrease (Carrefour Dufort to Mariani) of over 1,000 metric tons occurs just before the core station controlling entry into Port-au-Prince from the entire southern peninsula.

Based on this analysis alone, it is difficult to determine if such trends in the passage of metric tons along the enumeration stations of National Highway 2 toward the capital represent:

1. Additions of charcoal;
2. Off-loading of charcoal before the capital;
3. Missed enumerations;
4. Misclassifications of vehicles; or
5. Some combination of all of these.

Figure 15 displays the counts of trucks passing through the same enumeration stations displayed in Figure 14. It appears that many of the large trucks are making the long haul toward the capital, through all the stations, in a progressively increasing number, with the exception of a small decline of large trucks between Carrefour Moussignac and Miragoâne. This trend also appears to be true of medium-sized trucks, with the exception of a small decline between Les Cayes and Carrefour Moussignac. Finally, in respect to small trucks, there is a gradual incline toward the capital, with the exception of a slight dropoff between Miragoâne and Carrefour Dufort.

However, Figure 16 makes it clear: the sudden decline of overall metric tonnage between the Dufort and Mariani enumeration stations is due to a sudden drop in the number of all types of trucks entering Port-au-Prince.

The 1,138 metric tons of charcoal unaccounted for between the Dufort enumeration station and the final Mariani enumeration station is best explained by the prior passage of National

FIGURE 15: Trucks Passing Through the Enumeration Stations of the Southern Peninsula

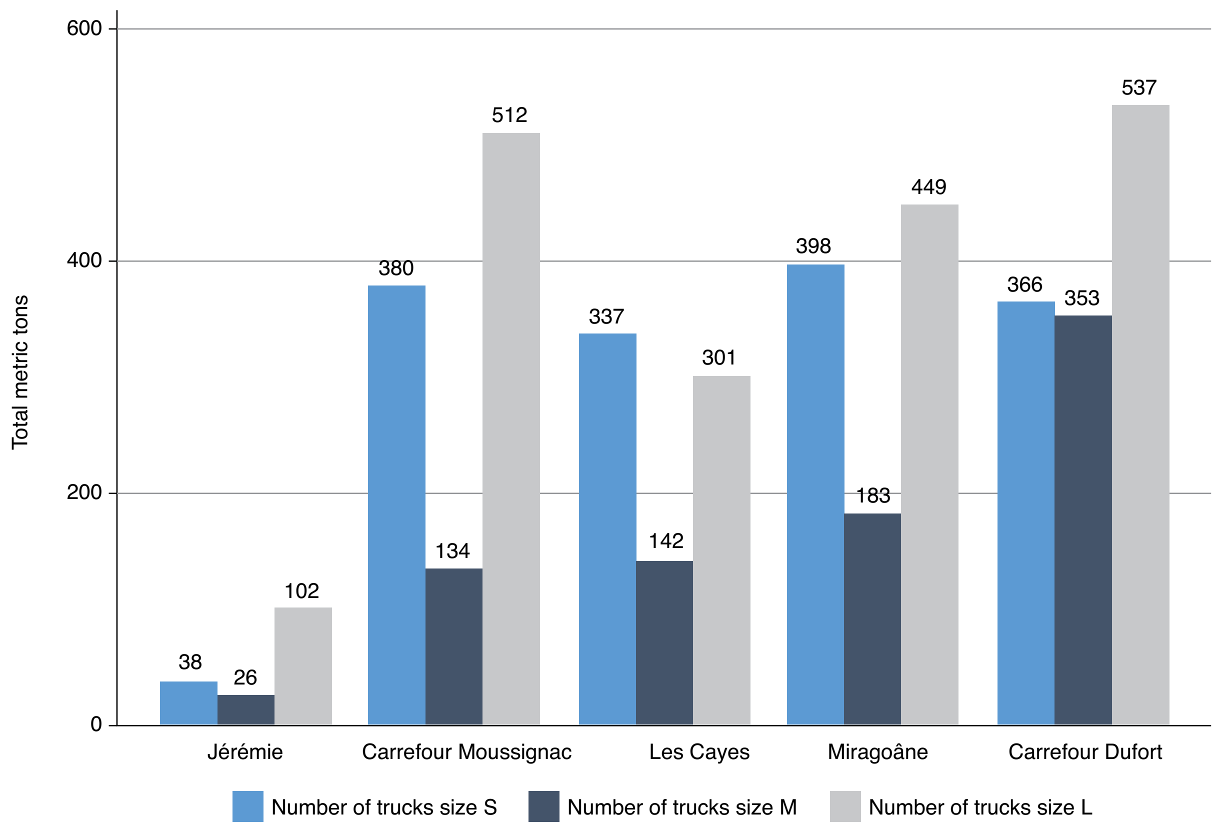
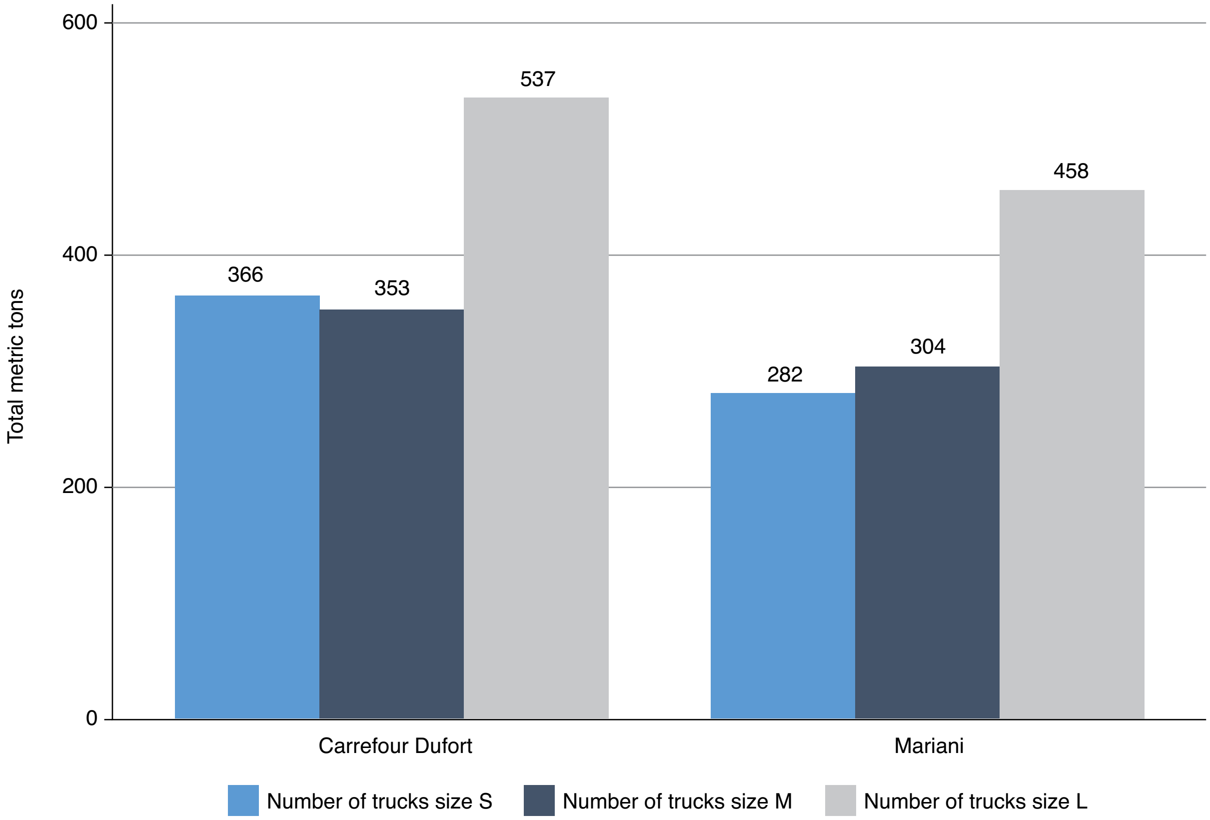


FIGURE 16: Trucks Passing Through the Last Two Stations on the Western Peninsula



Highway 2 through the city of Léogâne, with a population of over half a million at the *arrondissement* (municipal level). By comparison, the arrondissement population of some of the other large cities found *en route* along the southern peninsula toward Port-au-Prince include: Jérémie (238,218); Les Cayes (346,276); and Miragoâne (141,826). While commensurate declines might be expected between the Jérémie, Les Cayes, and Miragoâne stations based on their urban populations, these other cities are surrounded by areas of high tree cover, while Léogâne has only Port-au-Prince to the east. Residents of Léogâne are thus reliant on and receive charcoal from only one direction along the national highway, whereas residents of other areas along the peninsula receive charcoal from multiple smaller 'feeder' roads that eventually join the national highways. These influences likely give incentive to drivers of large trucks to initially travel farther east along the peninsula to receive higher prices that are driven by higher demand.

Thus, the most plausible explanation for the drop in approximately 1,000 tons of charcoal prior to entry into the core is that truck drivers are off-loading large quantities of charcoal in Léogâne because the prices are comparable to those in Port-au-Prince, there is a large population willing (needing) to purchase the charcoal, and the trip is notably shorter.

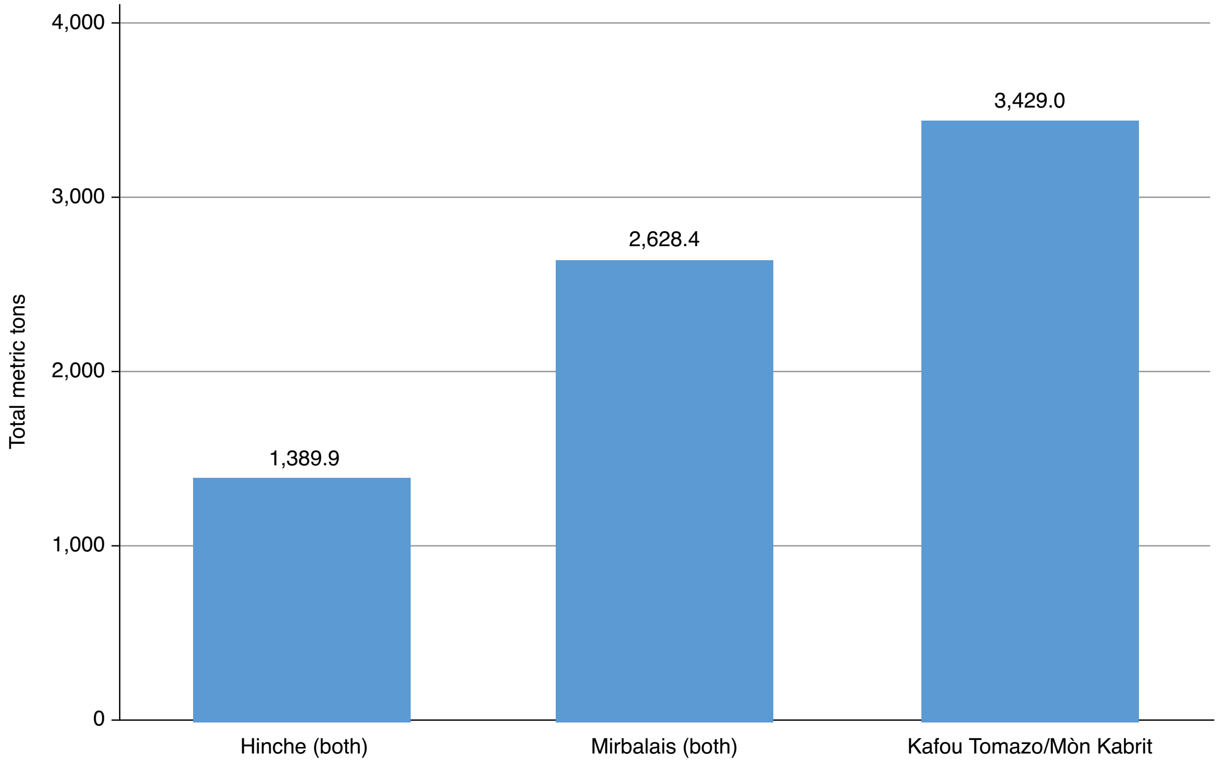
Central Plateau

Some of the same trends noted for the southern peninsula are repeated on the route from the Central Plateau toward Port-au-Prince, where five different enumeration stations were placed at multiple intersections.

Figure 17 groups together the two stations at Hinche, the two stations at Mirebalais, the core station at Kafou Tomazo/Mòn Kabrit, while excluding the inputs from all feeder roads. In this formation, we see an expected trend: metric tons increasing along the national highway toward Port-au-Prince.

However, when not combining the counts of both different enumerations stations at Hinche and Mirebalais, and not discounting the charcoal counts from feeder roads, another picture emerges. Consider Figure 18, which presents data from the two stations at Hinche (farther north) and Mirebalais (farther south), respectively, in disaggregation.

FIGURE 17: Metric Tons En Route to Port-au-Prince from the Central Plateau.



Examining Figure 18, the pattern at Hinche makes logical sense, with a total of 919.6 metric tons entering the north of the city via RD308 and RN3 (enumeration station 'Hinche_1'), and a total of 826.7 metric tons recorded exiting the city through the southern enumeration station on RN3 (enumeration station 'Hinche_2'). When we consider an addition of 417.4 tons from RD306 (also enumeration station 'Hinche_2'), a total of 1,337 metric tons enters the city of Hinche, while only 826.7 metric tons leave the city of Hinche heading south on RN3. Therefore, it appears that 510.3 metric tons of charcoal are debarked in Hinche.

Enumerators at Mirebalais, the next city south on RN3 heading toward the capital, recorded a higher amount of charcoal (2,068.3 metric tons) at the northeastern entrance of the city (enumeration station 'Mirebalais_1'). The addition of approximately 1,200 tons of charcoal on the 56.5 kilometers between the cities of Hinche and Mirebalais is not surprising; this is one of the most tree-covered stretches of the highway passing through the Central Plateau.

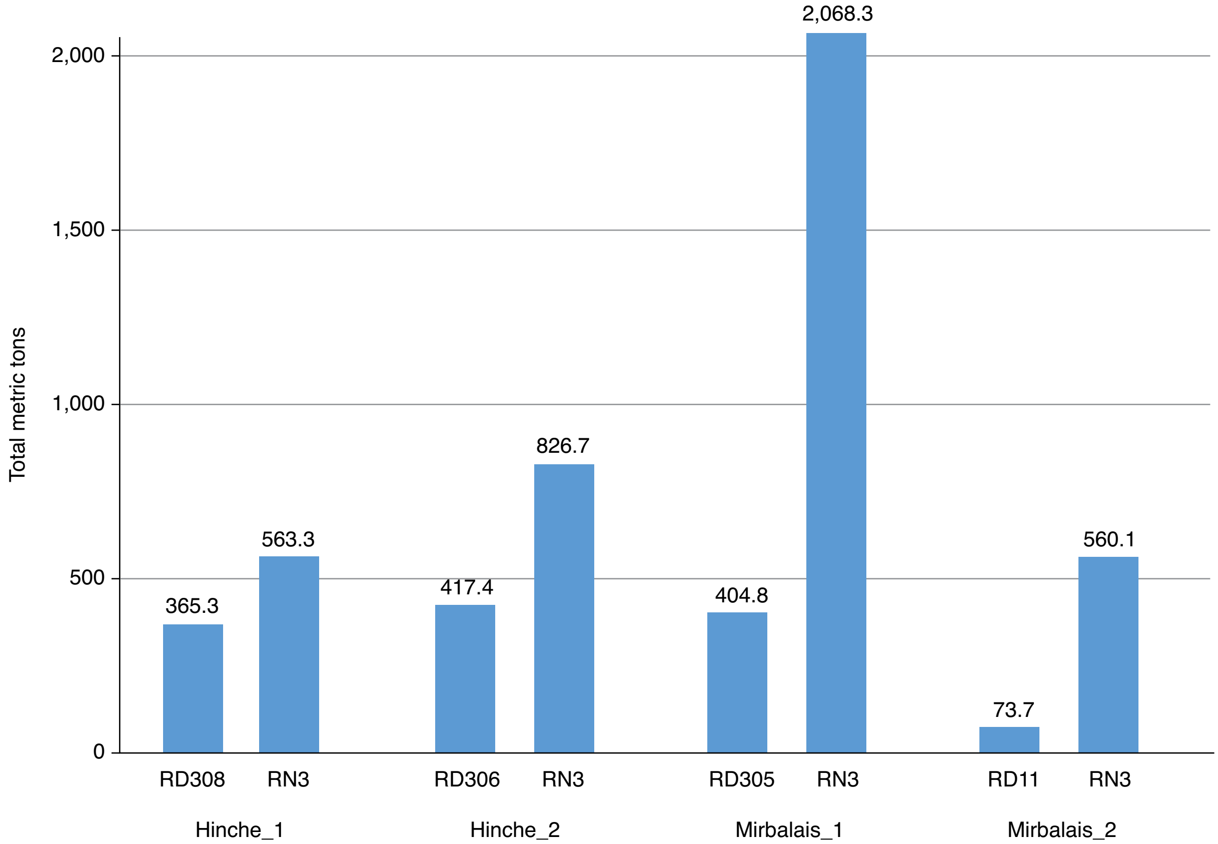
The *total* entrance of charcoal into Mirebalais via the northeastern entrance of the city (Mirebalais_1) when factoring in a 404.8 ton input from RD305 is 2,473.1 metric tons. At the southwestern enumeration station of the city (Mirebalais_2), an additional 73.7 tons are added by RD11 from the west, bringing the total amount of charcoal entering the city of Mirebalais to 2,546.9 metric tons.

However, only 560.1 metric tons of charcoal leaves the city of Mirebalais at the southwestern exit on RN3 (Mirebalais_2), meaning 1,986.7 metric tons are unaccounted for in passing through Mirebalais. Stated differently, more charcoal enters the city of Mirebalais than leaves the city, in a pattern similar to the one observed in Léogâne on the southern peninsula.

Mirebalais has a population of around 192,852 at the arrondissement level, while Hinche has a population of 264,943 at the same municipal level. In other words, comparing Hinche and Mirebalais, more charcoal went unaccounted for in the city with the slightly *lesser* population; population differences don't explain the missing volume of charcoal in Mirebalais.

It is probable that what occurred on the southern peninsula is also occurring here. Recall that a large amount of charcoal in the southern peninsula went unaccounted for between the station at Carrefour Dufort and the core station of Mariani, after passing through Léogâne, the last big city before the

FIGURE 18: Metric Tons of Charcoal Entering and Leaving Hinche and Mirebalais.



capital. Mirebalais occupies that same structural link or position in the charcoal transport chain of the Central Plateau, suggesting the truck drivers are unloading substantial tons of charcoal at Mirebalais for all the same reasons they likely did at Léogâne—charcoal likely sells in Mirebalais and Léogâne for prices comparable to those in Port-au-Prince; there are large populations in both Mirebalais and Léogâne willing to purchase this charcoal and offloading charcoal; at these locations reduces overall transportation costs, distances, and time[77] than traveling all the way into Port-au-Prince.

North

In the north there was an opposite trend from the one noted on the southern peninsula and in the Central Plateau area—rather than the disappearance of large amounts of charcoal at the last major city before core enumeration stations controlling entry into Port-au-Prince, there was a large, unaccounted for *surplus* of charcoal passing through the last core station controlling entry into the capital.

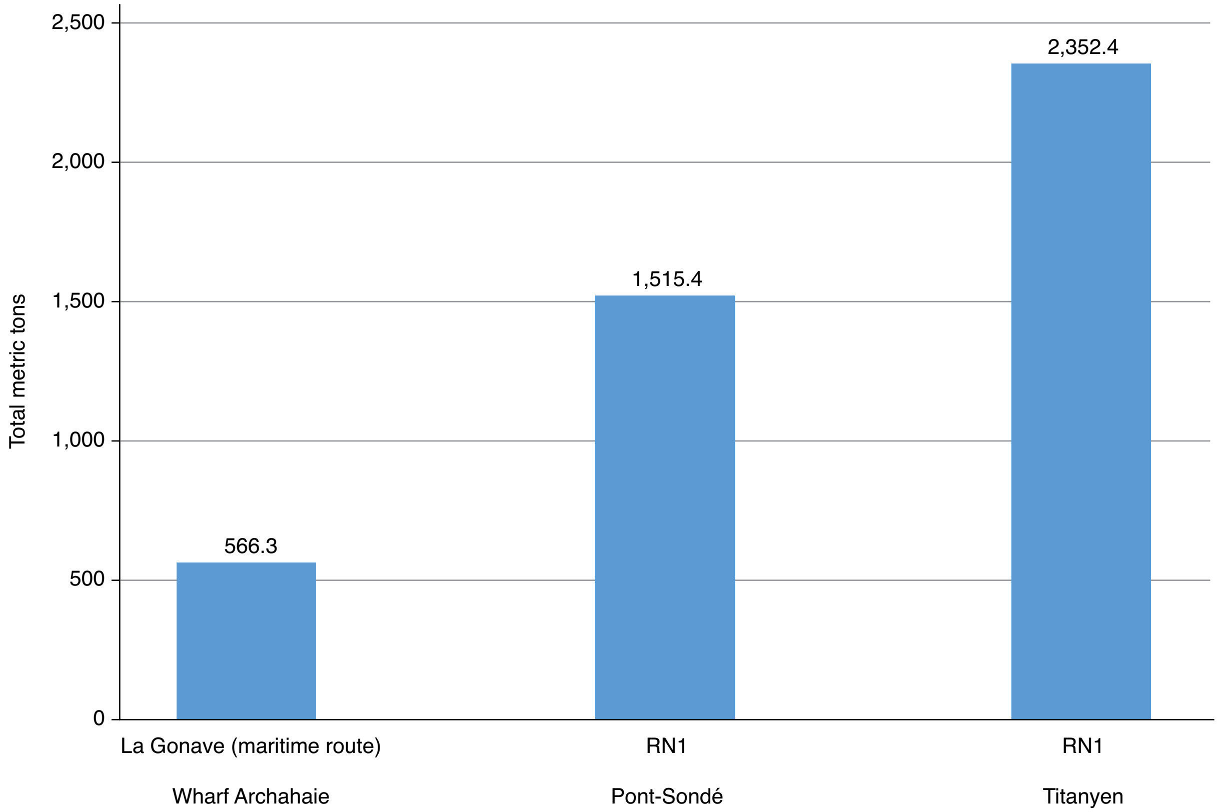
[77]Port-au-Prince has infamous traffic congestion.

Figure 19 displays the three stations counting charcoal originating in the northern (Artibonite) area, from the offshore island of La Gonâve and passing through the final core station at Titanyen. It should be noted that Wharf Archahaie counts were registered by enumerators at the seaside wharf as trucks left loaded with charcoal, not counted along National Highway #1. Therefore, Wharf Archahaie counts are almost assuredly double-counted in the Titanyen total displayed in Figure 19.

Pont-Sondé, in the heart of Artibonite, was the northern-most enumeration station in the study (not counting enumeration stations in the Central Plateau area). When comparing the counts from Pont-Sondé (1,515.4 metric tons) to the counts from the core enumeration station at Titanyen—without counting the Wharf Archahaie counts and the small amount coming from the feeder road at Titanyen (nine metric tons)—we found an *additional* 261.7 metric tons of unaccounted for charcoal between these two locations.

Since there are several cities and towns of notable size between Pont Sondé and Titanyen—St. Marc (pop. 443,007), Archahaie

FIGURE 19: Metric Tons of Charcoal Entering Port-au-Prince from the North



(pop. 130,306), and Cabaret (pop. 68,245)[78]—the *addition* of 261.7 metric tons of charcoal is an unexpected and surprising discovery. There are few substantial feeder roads leading from National Highway 2 into the barren western coast of Haiti that could have provided this volume of charcoal, and the Titanyen enumeration station controlled for the only such road (RD113) that connects to other major roads, in this case roads leading to the Central Plateau area. But the RD113 feeder road registered only nine tons of charcoal total during the combined sampling periods. And charcoal is rarely observed for sale alongside RN1 between Titanyen and Pont Sondé.

The 261.7 additional metric tons of unaccounted for charcoal noted at Titanyen is approximately half the volume of charcoal incoming to Wharf Archahaie. The historical literature suggested that Wharf Archahaie received charcoal from the Island of La Gonâve *and* from the Northwestern peninsula. However, during data collection, informants at Wharf Archahaie indicated all incoming charcoal originated from the island of La Gonâve.[79]

One hypothesis is that the 261.7 metric tons of charcoal enumerated at Titanyen but not accounted for by Pont Sondé or Wharf Archahaie came from the northwest peninsula, making landfall at the St. Marc wharf, which comes *after* the Pont Sondé enumeration station on RN#1. The St. Marc wharf is a much shorter distance for boats coming from the northwestern peninsula, and both the improvement of RN#1 since earlier studies, and the growth of St. Marc, have likely redirected much of the maritime charcoal traffic originating in the northwest toward Wharf St. Marc. Seasonal variations in wind or ocean currents may have also played a factor.

[78]St. Marc and Archahaie populations are noted at the *arrondissement* level; Cabaret is noted at the commune level.

[79]When visiting this Wharf during preliminary scouting, it appeared that charcoal from La Gonâve was stacked on one side, and charcoal from the Northwest was stacked on another side. However, enumerators indicated that virtually all the charcoal they counted originated from the island of La Gonâve. This result is puzzling, and could have origins in enumerator errors, or some sort of seasonal transportation variability related to the currents, tides, or waves of the sea.

East of Port-au-Prince

The literature suggests that the area east of Port-au-Prince was the first location of charcoal production to supply the city, but by 1978 it was supplying only 5 percent (Voltaire 1979). But this figure increased to 5.6 percent by 1985 (Grosenick and McGowan 1986) and continued increasing to an estimated 11 percent by 1990 (ESMAP 1991).

We know from Figure 11 that the second largest flow of charcoal enters the capital from the east, when considering the counts enumerated at the Croix-des-Bouquets station (21.15%) joined with counts from the feeder road at the Thomazeau/Mòn Kabrit station (3.39%), which represents a total of 24.54 percent of the total volume of charcoal consumed in Port-au-Prince.

However, while approximately one-fourth of the charcoal *enters* the capital from the east, when determining the amount that *originates* from *due* east of the capital, some arithmetic is required: the counts from the Croix-des-Bouquets station and the feeder road at Thomazeau/Mòn Kabrit require the subtraction of charcoal that originated from the *southeast* of Haiti, and from the Dominican Republic, registered at the previous enumeration station near Malpasse.[80]

After these controls are made, the charcoal with origins *due* east of Port-au-Prince amounts to 2,994.56 metric tons during the two weeks sampled, or 17.76 percent of the charcoal consumed in Port-au-Prince during the same period.

Charcoal Entering Haiti from the Dominican Republic

Estimates of Charcoal Entering Haiti from the Dominican Republic

Counts from all five enumeration stations controlling for charcoal entering Haiti from the Dominican Republic (DR) yielded minimal results. Three of the five stations (Belladere, east of Mirebalais; Anse a Pitre, in the southeast; and Wharf of Marigot near Jacmel) registered no observations originating from the DR and therefore are not displayed in Table 7.

[80]See the subsequent section on charcoal entering from the Dominican Republic and changes in charcoal production over time for more details.

TABLE 7: Charcoal Observed Entering Haiti from the Dominican Republic, as % of Amount Consumed in Port-au-Prince

Location	Total	Disaggregates
Malpasse	1.28%	
Cerca La Source (east of Hinche)	1.00%	0.438% (Cerca La Source Rd.)
		0.571% (Route Dania & Garde Salnave)
Total	**2.28%**	

The primary charcoal border importation location described in the literature and identified by multiple informants in Phase I of the research schedule is Malpasse, just east of Port-au-Prince. Once a week, multiple small boats debark from the northeastern shore of Lake Azuéi (Saumâtre in the DR), which falls almost entirely within the border of Haiti but borders the Dominican Republic on the northeastern side. These boats land and disembark charcoal on the southwestern side of the lake, and this charcoal is then loaded onto trucks that drive it toward Port-au-Prince. However, the amount of charcoal entering Haiti at Malpasse on Route National Number 8 during both sampling periods was 215.82 metric tons (an amount equivalent to 1.28 percent of the total charcoal transported into Port-au-Prince during that same period).

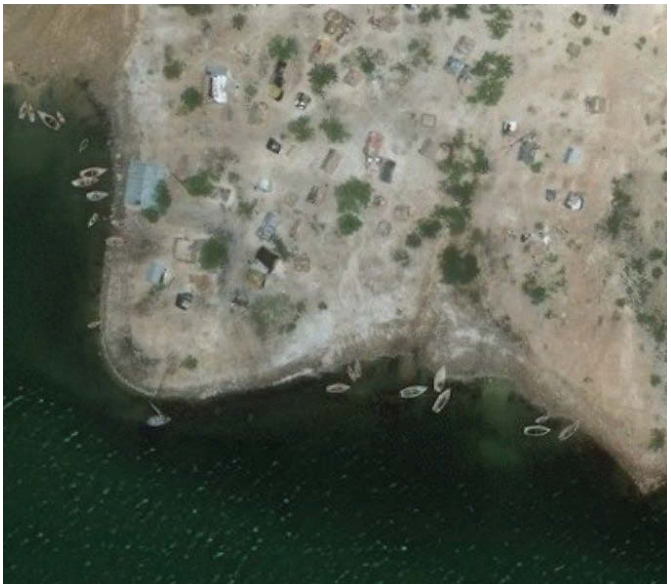
Therefore, based on the data included in Table 8 above, the amount of charcoal entering Haiti from the Dominican Republic is equivalent to 2.28 percent of the total amount of charcoal consumed in Port-au-Prince. However, it is possible that charcoal may be entering Haiti from Route National Number 6 along the northern coast of Haiti, or through wharfs along the northern coast of Haiti (the only known major entry routes we did not control for), although the transportation of such charcoal would logically be geared toward consumers in nearby Cap Haitian (the third largest city in Haiti), rather than incurring time and transport costs to arrive all the way south to Port-au-Prince.

Alternative Hypotheses Concerning Charcoal Entering from the Dominican Republic

Some readers might be tempted to conclude that the gradual increase in charcoal production east of Port-au-Prince over the last 40 years (supported by the literature and data) actually represents charcoal arriving clandestinely from the Dominican Republic through other locations.

FIGURE 20: Two Similar Wharfs on the Eastern Side of Lake Azuéi (Saumâtre)

Left: Malpasse



Right: new location

Considering that such a scenario might be possible, the research team examined multiple satellite images and located only one other site on the northeastern (Dominican Republic) side of Lake Azuéi (also called Lake Saumâtre) that could possibly represent a charcoal transportation site similar in capacity to the one at Malpasse (see Figure 20).[81] Interestingly, both locations in Figure 20 are technically on the Haiti side of the border, albeit right along the border with the Dominican Republic.

Both wharfs featured in Figure 20 appear similar in size (considering the number of boats and structures), but where Malpasse was paired with one wharf on the western (Haiti) side of the lake, the second location appears to possibly be paired with two different wharfs on the western side of the lake (one area near the end of the road to Thomazeau; and another area west of Malpasse near Fond Parisien, on the same road leading to Croix-des-Bouquets and onward into Port-au-Prince (Route National 8).

[81]The same commentary made in regard to potential donkey transport applies in this case. While within-country transportation of charcoal into Port-au-Prince used to occur with donkeys, those days have largely ended with the introduction of motorcycles. Donkeys are still used in rural areas with poor access to major transportation routes, but people debark charcoal at specific locations, including wharfs, where larger transport vehicles arrive. Thus, it is highly unlikely that donkeys are making a substantial cross-border transport of charcoal. Even if they were, the propensity to offload beasts of burden for loading onto trucks or boats virtually assures we would have captured such transport.

Although it is possible, even likely, that *some* charcoal is passing from this second wharf identified on the Dominican Republic side of the lake, only a small percentage of charcoal (1.28 percent of the amount entering Port-au-Prince) crosses over at Malpasse. It would be a large jump to presume that this second site furbishes the remaining 16.48 percent of the estimated 17.76 percent of charcoal originating due east of the capital. Such an assumption would also run contrary to several very different sources of evidence:

- All the literature, multiple key informants, and all those participating in contextual interviews conducted during Phase I indicated Malpasse as the primary cross-border charcoal transfer location;
- There is more profitable contraband to import from the Dominican Republic that would be of higher interest to boatmen ferrying small loads in tiny boats (e.g. sausage, eggs, cement, etc.).
- A joint publication of the Haitian Ministries for Public Works, Transportation and Communications; Bureau of Mines and Energy; and Electricity in 2005 noted the area east of Port-au-Prince as a prime location for 'energetic forests' of *bayawonn* woodlots (*Prosopis juliflora*). (ESMAP 2005, 18). This is how the area east of Port-au-Prince has been described in the literature from the 1970s onward.
- Recent visits to this area by the research team indicate that these areas are still very much defined by coppicing

Prosopis trees that are managed along a woodland-to-woodlot spectrum for charcoal production;

- Multiple historical references, published within a decade after Haitian independence in 1804, report that the Plaine du Cul-de-Sac (former sugarcane plantations east of Port-au-Prince) rapidly became overgrown with *Prosopis juliflora* and *Haematoxylum campechianum* trees (the two most commonly used trees for charcoal production in Haiti since the 1920s);[82] and
- This rapid, historical increase of tree cover on former sugarcane plantations east of Port-au-Prince is not only noted in the historical literature; it is registered in fluctuations of arboreal pollen, weed types, and erosion in lake sediment analyses from Lake Miragoâne,[83] occurring during the same historical time period.[84]

Suffice to say, it would be neither historically unprecedented nor unlikely for an extensive and rapid increase in charcoal production east of Port-au-Prince, as research from 1978 onward suggests. According to the literature, charcoal production in the area due east of Port-au-Prince doubled in the five-year period between 1985 and 1990; for it to double again during the 27 years from 1990 to the present research (2017) seems safely within the realm of possibility.

Some of the factors that may be contributing to this reoccurrence of tree cover in the Plaine du Cul du Sac include a decline of soil fertility, increased soil salination, increased climatic drying, the decline of agricultural export crops, absentee land owners (many plots in this area are unusually large), and a host of other factors that work together to give incentive to residents east of Port-au-Prince to return to the production of charcoal. Whatever the causal factors, the data demonstrate that charcoal entering from the Dominican Republic is much lower than previously believed.

[82]See Tarter 2015a.

[83]While Lake Miragoâne is located on the southern peninsula, Miragoâne was historically an important colonial port city with large plantations extending outward. Thus, the post-independence expansions of tree cover noted for Miragoâne register an event that happened at former plantation sites throughout the country.

[84]Brenner and Binford 1988, 94.

IV. Analysis

Estimated Annual Consumption in Port-au-Prince

To compute annual estimates for Port-au-Prince, the low and reconstructed peak weeks were extended to the entire year.[85] The resulting analysis assumes that charcoal trucks enter the capital at full capacity, and Port-au-Prince charcoal consumption can be approximated from the total flow of charcoal passing through the core enumeration points and into the city.

Table 8 presents the different methods used to estimate weekly and annual charcoal consumption for Port-au-Prince based on different hypotheses concerning the length of peak and low periods. The first two columns provide the total amount of weekly charcoal consumption in Port-au-Prince for the peak reconstructed period and the low period weeks.[86]

Column 3 provides the annual estimation charcoal consumption in Port-au-Prince based on the assumption that the year follows a normal calendar consisting of six peak months and six low months of charcoal production. The annual estimate of 438,204 metric tons of charcoal entering the core of Port-au-Prince, noted in bold in the table, is the most-prevalent scenario and is used as the standard throughout this report.

Column 4 estimates the annual charcoal consumption in Port-au-Prince under the scenario of a year with only three months of low and nine months of peak season charcoal production. This scenario could occur during drought years, or years with other types of unanticipated misfortune that would place poor households under additional financial duress.

Finally, column 5 estimates the scenario of a 'good' year composed of only three months of a peak charcoal production season. This case suggests a positive occurrence, for example, a well-targeted and functioning social safety net, or an increase in farmers' revenues, contributing to a decreased necessity for charcoal production.

These scenarios are particularly useful for future projections, present estimates, and recalculations of past charcoal consumption in Haiti, based either on known historical events or predictable or anticipated phenomena likely to impact seasonal variability in production across the year.

TABLE 8: Computation of the Annual Estimates of Charcoal Consumption in Port-au-Prince

	Week metric tons peak	Week metric tons low	6 months peak 6 months low	9 months peak 3 months low	3 months peak 9 months low
Low	7,437.75	6,101.25	352,014	369,388.5	334,639.5
Mid	9,256.125	7,597.875	438,204	459,761.25	416,646.75
High	11,074.5	9,094.5	524,394	550,134	498,654

[85] $Annual\ estimate = total\_Peak * \#Peak\ Weeks + total\_Low * \#Low\ Weeks$, where $total\_Peak$ and $total\_Low$ can take three values depending on whether the mid-, low-end, or high-end of the range is used.

For example, to compute the midrange annual estimate of charcoal consumption in Port-au-Prince, if we consider that both peak and low seasons last six months each (i.e., 26 weeks), we calculate: Annual estimate mid = $9{,}276.375 * 26 + 7{,}597.875 * 26 = 438{,}730.5$.

[86] See Section III for more theoretical and empirical evidence.

Changes in the Regional Supply of Charcoal to Port-au-Prince

Parsing the changes in charcoal *production locations* and *consumption quantities* over time in Haiti is a challenging endeavor. Many previous studies of charcoal production and consumption in Haiti are based on one of two principal approaches: (1) the Count Approach (typically based on the placement of enumeration stations around the capital city of Port-au-Prince, sometimes further out); and (2) the Consumption Approach[87] (typically based on household surveys of self-reported or observed charcoal consumption rates). Both of these approaches are confronted with assumptions and challenges, such as:

- A historical assumption was that the vast majority of charcoal produced nationally was transported to and consumed in Port-au-Prince;
- One particular challenge is that there are many different approaches to measuring charcoal, either in bag counts, in tons, or in *mamits*.[88] Different weights have been ascribed to 'large' bags of charcoal, the range of weights for a large bag vary incredibly, and few researchers have noted that in different parts of Haiti there are variations on what constitutes a 'large' bag in the first place. The issue is not resolved by smaller, incremental measurements applied in many Consumption Approach studies.
- Another challenge is the differential manner in which previous studies have ascribed charcoal production *locations* throughout Haiti. In some studies, general areas are named (e.g., 'the northwest' or 'the south'), while in other studies such areas are clearly defined as the Northwest Department or the South Department. Complicating matters at the present time is the fact that Haiti went from nine to ten departments in the early 2000s.

Despite these challenges and assumptions, both the Count Approach and the Consumption Approach to estimating charcoal in Haiti have tended to make extrapolations to the capital and/or the nation using population estimates, and then forecast into the past or future using estimated population growth rates. Sometimes future projections are made based on previous estimated *counts* and sometimes they are based on previous *consumption* estimates.

The results presented here were controlled for all of these challenges by returning to original data tables of earlier research reports[89] and disaggregating data to best align locations of departments and generalized areas, to recalculate tons using a standardized weight of a large charcoal bag (30 kg), and any other necessary data standardizations. The data points on the y-axis of Figure 21 represent this data standardization, and the years on the x-axis were adjusted to reflect the year that data from different research reports were collected, or the year that estimates were projected to, rather than the year the research reports were published. In several instances, Figure 21 displays estimates based on both *counts* and *consumption* rates that appeared within the same reports.

What is most remarkable is that, despite the differences in approaches, both methods trace a close linear progression over time. In most instances, *count* approaches have yielded slightly lower estimates than *consumption* approaches.

Table 9 displays regional percentages for charcoal entering and consumed in Port au Prince, and should not be mistaken as overall regional percentages of charcoal production at the national level. This approach follows the convention of previous reports and permits tentative conclusions about changes in charcoal production locations over time. The ESMAP (2007) study is conspicuously absent because it did not clearly delineate areas of production.

Several clear, diachronic trends are immediately apparent from Table 9. The northwestern area of Haiti has continued to decline over the last four decades, falling from its former position of providing 50 percent of the charcoal consumed Port-au-Prince. Likewise, the island of La Gonâve has continued to decline in the overall percentage supplied to the

[87] These differences in approach to charcoal estimates in Haiti were first elucidated by Stevenson (1989, 71–72).

[88] A 'mamit' is the Haitian Creole name for a large tin coffee can, and it is a common though imprecise measurement used in markets throughout Haiti. Anthropologist Sidney Mintz described a 'gwo mamit' from nearby Fond-des-Negres as the ". . . most important of all solids measures. It is the standard No. 10 can used to pack American foods such as catsup, applesauce, and lard for restaurant and institutional use. It holds five pounds of lard, and has a liquid volume capacity of 110.7 ounces," rightly noting it as "probably the most important measure in Haitian trade." (Mintz 1961: 28)

[89] Earl 1976, Voltaire 1979, Grosenick and McGowan 1986, ESMAP 1991, ESMAP 2007

FIGURE 21: Two Approaches to Annual Estimates of Charcoal Consumption in Port-au-Prince

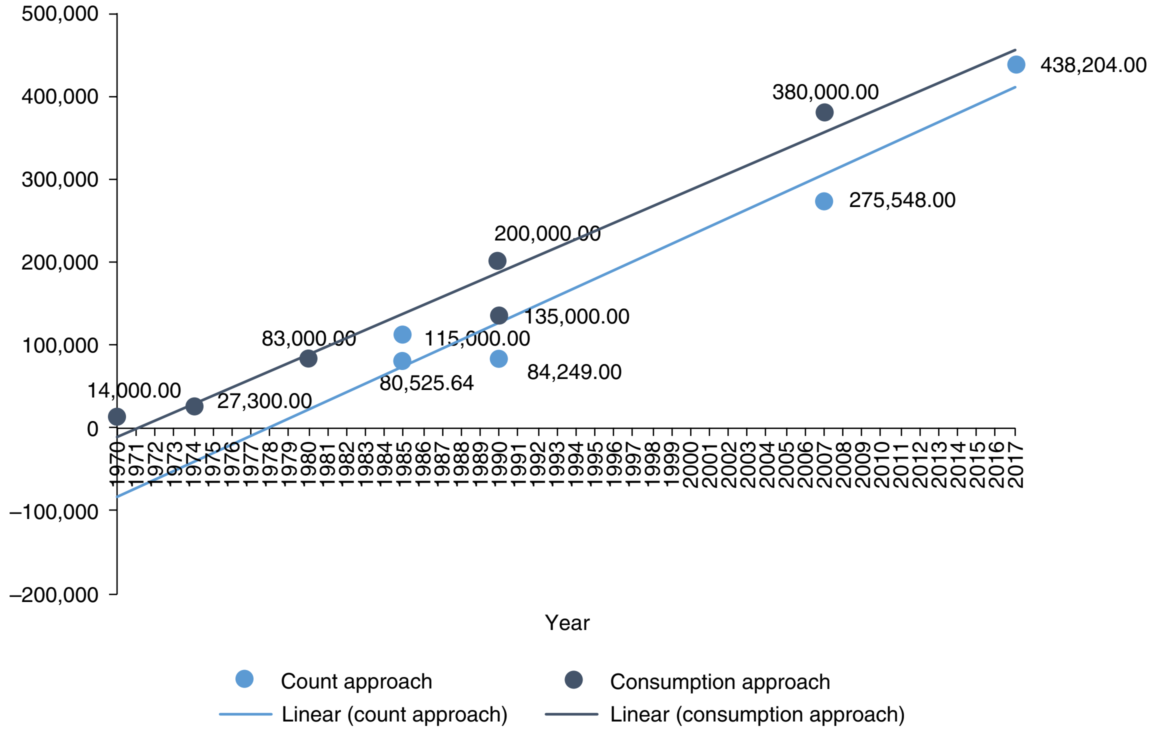


TABLE 9: Changes to origin of charcoal entering and consumed in Port-au-Prince

Location[90]	1978	1985[91]	1990[92]	2016[93] (our data)
Northwest	50%	34.2%	21%	1%
Island of La Gonâve	10%	7%	5%	3.4%
Artibonite	5%	4.8%	13%	9.7%
Central	N/A	2.3%	13%	20.3%
East of Port-au-Prince	5%	5.6%	11%	18%
Southern Peninsula (west of Mariani/Gressier + Wharf Jérémie)	30%	35.8%	30%	41%
Southeast	N/A	10.3%	3%	4.2%
South (Kenscoff/Furcy)	N/A	N/A	N/A	0.1%
North (department)	N/A	N/A	4%	N/A
Dominican Republic (Malpasse)	N/A	N/A	N/A	2.3%
Total	**100%**	**100%**	**100%**	**100%**

capital. The reverse is true of the Central Plateau area and the area east of Port-au-Prince, which yield increases in the percentage of charcoal consumed in the capital.

[90] General location, not Department.
[91] Several percentages reported by Grosenick and McGowan (1986) were strangely aggregated (for example, their 'Central' category, reported as 12.7%, encompassed Croix-des-Bouquets, Hinche, and St. Marc. But St. Marc is in the Artibonite, and Croix-des-Bouquets is east of Port-au-Prince. So we returned to their original data tables displaying counts of charcoal bags, to disaggregate their percentages and make estimates to adhere to the categories in our table.
[92] Estimated by disaggregation from their original tables (ESMAP 1991, pp. 13 and 99) and estimates.

The southern peninsula has remained surprisingly constant, continuing to provide at least one-third of the charcoal consumed in the capital over the last 40 years. Together, three areas (the Central Plateau area, the area east of Port-au-Prince, and the southern peninsula) supply approximately 80 percent of the charcoal consumed in Port-au-Prince. The

[93] These figures are different from Figure 11, which displays percentages of charcoal at the points of entry into the 'core' of Port-au-Prince from different general directions. The percentages displayed in Table 9 are further disaggregated *regionally*, by using data from the 'periphery' stations (see Figure 1).

area southeast of the capital and the Artibonite areas show less apparent linear trends. Other areas included (south and the Dominican Republic) were not reported across all categories and so no comparisons can be made over time.

Estimated Annual Consumption at the National Level

Using the midrange estimate of 438,204 metric tons of charcoal entering Port-au-Prince annually, a ratio of the annual tons of charcoal consumed in Port-au-Prince per person (a tons-to-population ratio) can be extended to the entire urban population of the nation.

The metropolitan population of Port-au-Prince, which encompasses all areas included in the 'core',[94] was estimated by the Haitian Government's IHSI[95] in 2015 at 2,618,894 people.[96]

However, the official number of urban dwellers in the country has been questioned. A 2017 World Bank publication "Haitian Cities: Actions for Today with an Eye on Tomorrow" undertook a thorough analysis to answer the question: What is urban? It uses satellite imagery to analyze population densities and produces an urban and nonurban classification at a high resolution. Results from this study show that the urban population in Haiti is likely much higher than official statistics. This analysis suggests that over six million people, or 64 percent of the total population of Haiti is urban, compared to an official statistic of 52 percent from the IHSI. It also suggests that each year as many as 133,000 Haitians become city dwellers.

Subsequent calculations use the official number for urban dwellers, but given emerging research on the definition of urban, these estimates should be considered conservative.

Dividing the midrange annual estimates of metric tons of charcoal consumed in Port-au-Prince by the population of Port-au-Prince yields a *tons-to-population* ratio of approximately 438,204 metric tons to 2,618,894 people, or 0.16 metric tons of charcoal consumed by person per year in Port-au-Prince.

TABLE 10: Per Capita Charcoal Consumption Estimate for Port-au-Prince

Range of metric tons	Annual metric ton	Individual quantity of charcoal, (in kg metric tons/ person/year
Low	352,014	0.134 metric tons
Mid	438,204	0.167 metric tons
High	524,394	0.200 metric tons

Table 10 extends this approach to also create ratios for the *low* and *high* end of the range.

Proceeding with the hypothesis that charcoal consumption in Port-au-Prince is equivalent across all urban areas in Haiti, we can estimate the total urban consumption of charcoal in Haiti to 946,504 metric tons as a midrange. This calculation is based on 5,667,686 people living in urban areas nationwide[97] and the 0.167 metric tons estimate of charcoal consumed per person annually in Port-au-Prince.

These estimates are based on the 2015 urban population numbers from the *L'Institut Haïtien de Statistique et d'Informatique (IHSI)*. Using the World Bank 2017 report on Haitian cities, the number of urban dwellers increases from 52 percent of the population to a more likely 64 percent of the population, with an estimated urban population of over six million people. Using official Haitian government population data has yielded a conservative estimate of national charcoal consumption.

Economic Value of the Charcoal Market

To explore the scale of the charcoal market in Port-au-Prince and nationwide, the study team commissioned a micro-assessment to collect current charcoal prices in August 2018. A field agent from the J/P Haitian Relief Organization "Haiti Takes Root" Initiative[98] collected prices for large sacks of charcoal at markets in Port-au-Prince. The field agent visited a total of five locations across the city and asked people working in the charcoal trade (n = 60) the sale price of a large sack of charcoal. Questions were posed to determine both the current price (August 2018),

[94]The communes of Port-au-Prince, Delmas, Cite Soleil, Tabarre, Carrefour, and Pétion-Ville.
[95]*L'Institut Haïtien de Statistique et d'Informatique.*
[96]IHSI 2015.

[97]Ibid.
[98]Haiti Takes Root is a Government of Haiti-led multi-actor initiative focused on reforestation and climate resilience in Haiti.

and to have respondents recall the price from the preceding month (July 2018). The mode and the average for both months is approximately 800[99] Haitian Gourdes[100] per large sack. The total volumes of the Port-au-Prince and national charcoal markets and price per 30 kg sack yielded price estimates of the value of the charcoal market.

The results are compelling: the total turnover in the Port-au-Prince charcoal market is approximately US$182 million per year. At the national level, total charcoal sales are an estimated US$392 million per year.

These figures are presented in Tables 11 and 12, alongside similar estimates from other studies conducted over the past 15 years.

The estimates of the total value of the national and Port-au-Prince charcoal markets are based on prices per large sack of charcoal, whereas a large but unknown percentage of urban charcoal consumers purchase their charcoal supplies in smaller units known as *mamits*, which are more affordable in the short term but have higher per unit prices than large sacks.

TABLE 11: Total Value of the Port-au-Prince Charcoal Market, in 2018 USD[101]

Total sales per year	Year of data	Source
$67,815,000[102]	2003	Angelier 2005
$106,637,076[103]	2005	ESMAP 2007
$181,496,774[104] (2017 USD)	2017 (charcoal quantities) & 2018 (charcoal sack prices)	Present study

[99]Mode = 800 Haitian Gourdes; Mean = 801.25 Haitian Gourdes.
[100]The average 2017 exchange rate for Haitian Gourdes to USD dollars (63.51223) was used when converting this figure to dollars in Tables 12 and 13.
[101]Adjusted to 2018 USD, based on cumulative annual inflation rates (per https://www.usinflationcalculator.com/, accessed on August 30, 2018).
[102]Authors' calculation is based on the estimated value of the national market ($66,000,000 USD 2003) (Angelier 2005, 25) * Port-au-Prince's contribution of ¾ of the total market (Angelier 2005, 21).
[103]Authors' calculation is based on original ESMAP 2007 data not ESMAP calculations: Since the ESMAP 2007 report uses figures that were rounded at several stages in their annual calculation to yield its calculation of 300,000 tons per year for Port-au-Prince, the authors returned to the original ESMAP data tables to extract the exact tonnage they observed before extrapolating the total Port-au-Prince market using their original counts (275,548). This figure was then multiplied by the $300/ton figure stated in study (ESMAP 2007, 4, 67).
[104]Based on the midrange estimate of 438,204 tons * estimate of 33.333 bags per ton (based on estimated average bag size of 30kg) * 800 Haitian Gourdes per bag/average exchange rate bid price for Haitian Gourdes to the US Dollar during Q1 2018 (64.38309) (Oanda.com, accessed on 08.26.2018).

Example of mamits

TABLE 12: Total Value of the National Charcoal Market, in 2018 USD[105]

Total sales per year	Year of data	Source
$ 90,420,000[106]	2003	Angelier 2005
$143,190,000[107]	2005	ESMAP 2007
$392,026,140[108]	2017 (charcoal counts) & 2018 (charcoal sack prices)	Present study

As a result, urban charcoal sellers make a considerable profit by dividing up a large sack of charcoal and selling it in smaller units. The estimate of the total value of the charcoal market is thus conservative—extending only the price of charcoal sold by the sack to the national level likely underestimates in this respect, as it does not include the markup for the practice of incremental charcoal sales. Nevertheless, these estimates provide a compelling sense of the enormity of the charcoal sector in Haiti. Even assuming a mid-point between these new calculations and findings from previous studies, it is clear that charcoal is one of the largest agricultural sectors in the country.

Charcoal as Compared to GDP

The economic significance of the charcoal industry can be put into context by comparing it to national GDP in Haiti. Based

[105] Ibid 119.
[106] Original estimate from Angelier 2005, 25.
[107] Authors' calculation is based on the midrange of ESMAP 2007's stated national annual tonnage (370,000–380,000) * $300/ton figure stated in study.
[108]Based on midrange national estimate of 946,504 tons * 33.333 bags per ton (based on estimated average bag size of 30 kg) * 800 Haitian Gourdes per bag/ average exchange rate bid price for Haitian Gourdes to the US Dollars during Q1 2018 (64.38309) (Oanda.com, accessed on 08.26.2018).

on 2017 GDP figures of US$8.408 billion,[109] charcoal represents 4.66% of GDP. In 2017, agriculture, forestry and fishing sectors represented 17.6 percent of GDP.[110] Given the above estimates of the total national value of the charcoal value chain ($392 million), the value of charcoal is 26 percent of total combined contribution of agriculture, forestry, and fishing to Haiti's GDP.

Charcoal Related to Other Commodities

The charcoal sector's outsized influence on Haiti's economy is also evidenced by its size relative to other agricultural commodities. Table 13 examines Haiti's top 15 agricultural commodities according to gross production values in 2016. When compared to the charcoal figures above, the data highlight that charcoal is the second largest ag-related value chain in the country, dwarfing most other traditional pillars of the Haitian rural economy, such as bananas, beans, avocados, coffee, sugarcane, and corn.

The only commodity that approaches charcoal's total value is mangoes. Interestingly, the total value of mango production has risen precipitously in recent years, from a relatively stable figure of approximately $150 million per year between 2000–2006, to nearly $502 million in 2016; this surprising finding merits further investigation.

TABLE 13: Gross Production Value by Commodity in 2016[111]

Product	Value (2018 USD)[112]
Mangoes, mangosteens, guavas	502,460,072
Meat indigenous, cattle	157,017,480
Yams	131,082,701
Bananas	93,124,205
Beans, dry	84,131,622
Avocados	80,730,687
Pigeon peas	76,389,616
Cassava	64,187,185
Meat indigenous, pig	63,394,243
Plantains and others	63,075,404
Sweet potatoes	61,399,264
Sugarcane	60,449,294
Coffee, green	55,381,818
Maize	53,829,298
Rice, paddy	48,890,674

Charcoal's importance to the Haitian economy is even more pronounced when compared with *export* values for key Haitian export crops. According to data from the FAO,[113] Haiti's total official exports of crops and livestock products (adjusted to 2018 USD) were valued at $62,479,200.[114] The national charcoal market is thus over six times larger than all of the country's other agricultural exports combined.

Table 14 shows export values for the top ten crop and livestock exports in 2016, highlighting yet again the scale of the national charcoal market, which is over 15 times larger than the top export product (essential oils). This fact is all the more striking given the substantial development assistance efforts undertaken over the past decades to support a number of these export crops, and the near complete lack of concomitant investments in charcoal.

The enormity of the charcoal sector translates into employment opportunities for large swaths of the rural population. As highlighted in previous research, charcoal is an extremely labor-intensive endeavor, with multiple actors intervening across the value chain; a recent study suggests that between four and eight people may be employed, between the private landowner that decides to harvest charcoal in a woodlot, to the final retailer in Port-au-Prince. (Tarter 2015a, 140–141) According to the ESMAP 2007 study, charcoal was responsible for 16 percent of combined rural incomes in Haiti. And a recent study by UNEP to map charcoal value chains in the south of Haiti noted that in the South department (one of the top sources of national charcoal production flows into Port-au-Prince) "approximately half of the rural population relies on charcoal and firewood production as either a primary or secondary source of income" (UNEP 2016, 20).

[109]Data.worldbank.org, accessed on August 25, 2018.
[110]"Agriculture, forestry, and fishing, value added (% of GDP)" from data.worldbank.org
[111]FAOSTAT database. http://www.fao.org/faostat/en/#home
[112]Adjusted to 2018 USD, using original dataset in 2004–2006 international dollars, and converting to 2018 USD using cumulative inflation rates.

[113]FAOSTAT database. http://www.fao.org/faostat/en/#home
[114]Authors' calculation using FAOSTAT dataset with the export value of all listed crop and livestock products.

TABLE 14: Top 10 Crop and Livestock Products, by Export Value (2016)[115]

Product	Value (2018 USD)[116]
Product	**Total value**
Oil, essentials	$25,510,800
Cocoa, beans	$13,249,950
Mangoes, mangosteens, guavas	$9,188,550
Oil, citronella	$3,605,700
Beverages, distilled alcoholic	$2,261,700
Beer of barley	$2,067,450
Crude materials	$1,340,850
Fruit, prepared	$1,338,750
Coffee, green	$611,100
Vegetables, fresh or dried products	$593,250

[115]FAOSTAT database. http://www.fao.org/faostat/en/#home

[116]Adjusted to 2018 USD, using original dataset in 2004–2006 international dollars, and converting to 2018 USD using cumulative inflation rates.

Employment in the Charcoal Market

In terms of total jobs created, previously cited estimates have placed national charcoal employment at 67,000 individuals,[117] which would represent 0.268 people per ton of charcoal produced, using the same study's nationwide estimates of tons of charcoal produced in 2003. Additional economic analyses are needed to ground-truth this ratio and its continued validity for today's charcoal sector, particularly given the variability in charcoal production systems around the country. However, applying this rough calculation to the research results above yields an estimated total of 253,663[118] individuals working in the national charcoal value chain.

[117]Angelier 2005.

[118]Estimates of 946,504 tons per year $*$ 0.268 people employed per ton.

V. Impact of Matthew on Charcoal Production

Disasters are caused or amplified by social, political, and natural events. Disasters sometimes offer a unique window into the robustness and resilience of linked social and ecological systems under duress. As an example, we present data from post-hurricane Matthew.

Hurricane Matthew

Hurricane Matthew served as a natural experiment that tested the robustness of the charcoal production system in Haiti. The Global Forest Watch's data analysis platform for Haiti[119] demonstrates the sheer magnitude of tree cover loss in one of the most tree-covered locations in Haiti, during the 2016 passage of Hurricane Matthew over the Grand Anse of Haiti.[120]

In 2016 the World Bank conducted an assessment to look at the number of trees affected by the passage of Hurricane Matthew (see Box 1 and Annex 5). Perhaps one of the most interesting findings from this research includes the fact that Hurricane Matthew did not appear to dramatically alter the flows of charcoal coming from the southern peninsula into the capital some ten months after the passage of the storm (when data from the first sampling period were collected) despite an incredibly large surge in available woodfuel and charcoal production, and an increase in farmgate prices by one-third across all sites. One would expect to see the percentage of charcoal entering Port-au-Prince from the southern peninsula to spike the enumeration counts at Mariani, due to the windfall of wood from Hurricane Matthew. Instead, this research shows the volume supplying virtually the same relative percentage to the capital as reported over the last 40 years. Furthermore, the Global Forest Watch's Haiti data confirms that after the hurricane's passage in 2016, tree cover losses normalized in 2017 to pre-storm levels.[121] These findings also point to a high level of resiliency in Haiti's charcoal supply system.

These and other disasters[122] have tested the robustness and resilience of the charcoal production system in Haiti. Matthew damaged the natural resource base of charcoal production systems, but the system survived and continues to provide charcoal throughout areas of Haiti.

[119] https://www.globalforestwatch.org/country/HTI

[120] https://www.globalforestwatch.org/HTI?category=forest-change&widget=treeLoss#treeLoss

[121] https://www.globalforestwatch.org/country/HTI

[122] The internal, urban-to-rural migration after the earthquake of 2010 (when rural populations temporarily swelled by some 10%), and the U.S. embargo on Haiti in the 1990s (Tanguay 1995) both provided tests of the robustness of the Haitian charcoal production system at the national level.

BOX 1. World Bank Arboreal Assessment Study

In 2015 Hurricane Matthew passed over Haiti, creating widespread damage and thrusting an estimated 800,000 to 1.55 million Haitians into a state of food insecurity, with approximately 280,000 categorized as severely food-insecure. The storm adversely affected crops, trees, and physical infrastructure, and an estimated 2 out of 3 farmers lost approximately 75 percent of their animal livestock (FAO 2017; UN World Food Program 2017). Agricultural damage assessments ranged from $573.5 million (the Haitian Ministry of Planning and External Cooperation) to $604 million (the Haitian Ministry of Agriculture, World Bank, and FAO) (FAO 2017). Total damages from the storm, from an estimation based on Haiti's 2015 GDP, were reported from to US$2.8 billion (approximately one-third of Haiti's GNP) (World Bank 2017) to US$8.88 billion (suggesting that Matthew destroyed the equivalent of 11.4% of the country's total production of goods and services).

The government-led Damage and Loss Assessment (DALA) conducted immediately following the storm used satellite imagery, interviews, and key conversations to determine losses across the country. In the agriculture sector, calculations included estimations of the value of crops lost, as well as damaged and lost trees. It was clear from this analysis that Hurricane Matthew's passage over the southern Tiburon Peninsula resulted in massive damage to arboreal systems, including: Haiti's remaining forests; fragmented tree stands; and a multitude of individual trees found on farms, in courtyards, on steep slopes, in deep ravines, along riverbanks, delineating property boundaries, lining roadsides, and in other isolated locations. The storm's damage to trees ranged from complete felling, to snapping of trunks at various heights, to snapped branches, to partial or total loss of foliage. However, it proved difficult to decipher satellite imagery for damaged, broken trees, or standing dead trees versus standing live trees, and due to this the full impact of the storm on tree resources was not fully known.

As such, the World Bank team undertook a Post-Hurricane Matthew arboreal assessment of the Grand Anse and Sud Departments (composing the lion's share of an area colloquially referred to as the 'Grand Sud') of Haiti—the areas hardest hit by the storm. The study was conducted approximately 10 months and two agricultural seasons after the passage of Hurricane Matthew. The time that passed since the phenomena of interest permitted trees to recover, ensured that answers to questions more accurately reflected final outcomes for trees, permitted tree-based markets to stabilize, and allowed for a better understanding of how farmers used newly opened lands in the subsequent agricultural season.

The main results of the study demonstrated the types of trees fallen across the sample region and the uses of these trees by the farmers, with strong implications for the charcoal market. Fallen coconut, breadfruit, and mango trees together represented 52 percent of all of the fallen trees. Farmers who owned the plots of land where sample transects took place were asked about their primary use of trees knocked over during the storm. Across the samples from all regions, Haitian farmers overwhelmingly produced charcoal from trees felled during Hurricane Matthew.

See a full summary in Annex 5.

VI. Conclusion

Research Questions

The research presented in this report was conducted over two years, commencing in 2016 with literature reviews, key informant interviews, and regional scouting trips in Port-au-Prince and across Haiti to identify the best locations for charcoal truck and charcoal boat enumeration stations. These stages were followed by three different sampling periods in 2017 (August, October, and December) that amounted to a total of 384 hours of enumerations, registering 10,404 unique observations by 69 enumerators at 23 different stations controlling multiple intersections of roads or maritime wharfs leading into Port-au-Prince from every direction of the country. The following brief summaries address the research questions introduced in Section II.

- (**R1**) How much charcoal is consumed annually in the capital city of Port-au-Prince?
- (**R2**) Which geographical regions produce the charcoal consumed in the capital?
- (**R3**) How do these production areas variably supply charcoal to the capital?
- (**R4**) In what ways have these trends changed over the last 40 years?
- (**R5**) What percentage of charcoal consumed in the capital is originating from the bordering Dominican Republic?

R1: Charcoal Consumed Annually in the Capital City of Port-au-Prince

The annual charcoal consumption range for Port-au-Prince is based on 24/7 counts at six key enumeration stations accounting for the largest known charcoal entry points into the capital. Assuming six months of charcoal production high season and six months of charcoal production low season across a typical year, an estimated 352,014 to 524,394 metric tons of charcoal enter Port-au-Prince annually, with a midrange estimate of approximately 438,204 metric tons per year. This midrange estimate for Port-au-Prince is consistent with other historical studies that used either consumption-based or count-based approaches.

The estimated *national* charcoal consumption range per year for Haiti is based on the *tons-to-population* ratio developed using Port-au-Prince—by far the largest city and largest consumer of charcoal in the country. The tons-to-population ratio was applied to the entire urban population of Haiti (inclusive of Port-au-Prince) as last reported by the Haitian government (IHSI 2015), yielding a range between 759,470 and 1,133,537 metric tons, with an estimated midpoint of 946,504 metric tons per year.

R2, R3, and R4: Geographical Origins and Trends of Charcoal Consumed in the Capital

Many of the predictions about the charcoal trade in Haiti made by Karl Voltaire nearly 40 years ago have come true (Voltaire 1979). For example, charcoal produced to supply the capital has indeed shifted dramatically into the Central Plateau area (+ ~20%) and declined in the northwestern peninsula (– ~49%) and the island of La Gonâve (– ~5%). However, regions of Haiti that Voltaire implied might become exhausted of woodfuel reserves have instead increased their supply of charcoal to Port-au-Prince, including the Artibonite region (+ ~5%) and the area east of the capital (+ ~15%).

Other geographical areas that Voltaire did not note as charcoal production zones nor predict as future charcoal supply regions to the capital include the Dominican Republic (~2%) and the southeast region of Haiti (~4%). Voltaire estimated that the southern peninsula supplied approximately one-third of the charcoal consumed in Port-au-Prince in 1979, and that estimate has remained stable across two subsequent studies conducted in 1985 and 1990 (the present research reported 41 percent in 2017).

Table 9 in the main body of this report notes all of these changes and lists the current percentages of charcoal that different regions are believed to be supplying to the capital city of Port-au-Prince in 2016: northwest (1%); Island of La Gonâve (3.4%); Artibonite: (9.7%); central (20.3%); east of Port-au-Prince (18%); the southern peninsula (41%); southeast (4.2%); due south of Port-au-Prince/Kenscoff/Furcy (.1%); and the Dominican Republic (2.3%).

It should be noted that all these figures represent changes in the *relative* supply of charcoal to the capital, not the *overall* supply originating from a given region—a crucially important point. Grosenick and McGowan (1986) first made this important distinction between relative production versus overall production of charcoal in relation to the findings of their research. Presuming Voltaire's (1979) assessments of the geography of charcoal production in Haiti were correct, while the supply of charcoal from the northwest had fallen from 50 percent to 34.2 percent of all charcoal consumed in Port-au-Prince by 1985, Grosenick and McGowan suggest that the *amount* of charcoal consumed in Port-au-Prince had more than doubled (1986). Thus, between 1978 and 1985, overall charcoal production had actually *increased* in every existing charcoal zone: by 45 percent in the Northwest; by 50 percent on La Gônave; by 100 percent in the south; and by 170 percent in the Central Plateau (Grosenick and McGowan 1986, 6). Extending this trend to the present research, the annual estimate for Port-au-Prince in 2018 is at least five times that of Grosenick and McGowan for 1985, suggesting that *overall* charcoal production has likely increased in virtually every area sampled, including those that show a decline in the *relative* percent of charcoal supplied to Port-au-Prince.

Thus, Haitians are not only still meeting their woodfuel needs, contrary to Voltaire's predictions of an eventual exhaustion of supplies and the potential for a subsequent environmental collapse; Haitians are continuing to meet their woodfuel demands from most of the same regions, and at much higher volumes of production.

In attempting to address this seeming contradiction of a Haiti with a significant cover of trees and shrubs, continuing over time to increase production of charcoal, a common but misguided assumption is that a large portion of charcoal consumed in Haiti originates in the neighboring Dominican Republic. This theory is propagated by a combination of old or incorrect data, extrapolation errors, and the lack of proper contextualization.

R5: Percentage of Charcoal Imported from the Dominican Republic

The last major study to examine charcoal crossing over into Haiti from the Dominican Republic was undertaken in 2005, which estimated some 5,475 tons enter at Malpasse per year (ESMAP 2007, 21). When the ESMAP figure is disaggregated back to the original figure from a week-long sampling period, it yields a flow of some 105.7 metric tons of charcoal per week (5,475 tons ÷ 52 weeks/year). In 2017, the enumeration station at Malpasse counted a highly congruent figure during both weeks of sampling (215.81 metric tons; ~107 tons/week), an amount equivalent to 1.3 percent of the total charcoal consumed in Port-au-Prince during that same period. Across all five different enumeration stations controlling for charcoal entering Haiti from the Dominican Republic during that period, the total amount of charcoal observed in the research presented in this report is equivalent to 2.28 percent of the amount consumed in Port-au-Prince. In summary, contrary to popular belief, the data show that a negligible amount of the charcoal consumed in Haiti originates in the Dominican Republic.

Data from the Massachusetts Institute of Technology's Observatory of Economic Complexity (MIT OEC) shows a shifting trend in official charcoal exports from the Dominican Republic. In 2001, Haiti received over 50 percent of official Dominican Republic charcoal exports, which were valued at only US$4k. By 2011, official exports of charcoal to Haiti were down to 17 percent, while the 2012 value of Dominican Republic charcoal exports had grown to between US$500 k–US$1.2 m, with no official exports destined to Haiti (by 2012, exports were exclusively to the U.S., Europe and the Middle East).[123] The simultaneous shift away from official exportation of charcoal to Haiti and the increase in the value of the charcoal market in the Dominican Republic indicate new charcoal markets of higher value were found elsewhere.

If charcoal was no longer being legally imported into Haiti by 2012, perhaps it was still being smuggled clandestinely over the border, as some have suggested. Even if the new markets for Dominican Republic–produced charcoal did not exist, leaving

[123]https://atlas.media.mit.edu/en/visualize/tree_map/hs92/export/dom/show/4402/2016/

Haiti as the only viable market, there still are much more profitable contraband items that are smuggled into Haiti from the Dominican Republic than charcoal. To underscore this reality, consider that the Associated Press reported in August of 2018 that Dominican and Haitian authorities exchanged gunfire, wounding three Haitian soldiers and one Dominican soldier, over the smuggling of cement into Haiti near Belladère,[124] one of the five border regions controlled for charcoal enumeration in the present study. The event solicited official responses from the President of Haiti and Dominican officials. Since 2015, the Haitian Ministry of Economy and Finance (MEF) has banned at least 23 different products from importation into Haiti from the neighboring Dominican Republic—with many of these products far exceeding charcoal in value relative to transport and import costs—in an effort to crack down on revenues lost from cross-border smuggling.

New, more profitable overseas markets for Dominican-produced charcoal, the low profitability of smuggling charcoal into Haiti relative to other in-demand contraband, the costs and time associated with transportation and importation of charcoal, and other risks along the border, likely all contribute to the decreasing and now negligible flows of charcoal from the Dominican Republic into Haiti observed since 2005 (ESMAP 2007) and observed in the present research.

Yet the question remains—how have Haitians been able to continue to meet their increasing charcoal consumption demands if not through supplemental imports from the neighboring Dominican Republic?

Explaining Increases in Production

Several plausible hypotheses have been suggested[125] to rectify how on the one hand, the Haitian landscape has experienced incredible overall increases (100–200%) in charcoal production between 1978 and 1985,[126] and commensurate increases in subsequent years (see Figure 21), while on the other hand, multiple, recent analyses indicate a much higher tree cover for Haiti than previously believed[127] and a lower-than-expected annual rate of decline of aboveground woody biomass predicted in complex environmental modeling of Haiti's woodfuel situation:[128]

1. *Haiti was not as devoid of tree cover as initially believed.*

High-resolution satellite imagery has only recently become widely available. Previously, estimates of tree cover in Haiti relied on (1) assessments from aerial flyovers—often from commercial airlines with a flight trajectory over some of Haiti's most denuded areas; and (2) field site visits by researchers that were limited in travel to areas of Haiti that were accessible by vehicles, which are paradoxically the same areas most likely to be denuded due to such area's equal accessibility to markets.[129]

2. *The creation of over 1,000 new kilometers of roads opened up previously remote areas of Haiti to charcoal production and reduced pressure on existing charcoal-producing areas.*

According to Voltaire the main obstacle for reaching the remaining wood stores in Haiti to meet demand until the turn of the new millennium was *transportation.* (Voltaire 1979, 21) The groundwork for the eventual decentralization of charcoal production in Haiti was prepared by the U.S. Marine invasion and occupation (1919–1934) with an emphasis, among other things, on shoring up existing and establishing new transportation infrastructure, including roads, railways, and maritime wharfs.

Later, *Harmonisation de l'Action des Communautes Haitiennes Organisees* (HACHO), a community-based organization, constructed a network of 600 kilometers of new unpaved roads in the northwest of Haiti between 1968 and 1982 (Brinkerhoff et al. 1983, 4–5, 17). Three hundred kilometers of 'jeep roads' were added to the island of La Gonâve, starting in the late 1960s, and although there was virtually no vehicular traffic on

[124]https://www.apnews.com/da3808d6ce384bf0b4adbc4deee6a79b
[125]Tarter 2015a; Tarter 2016; Tarter et al. 2016, 24–26.
[126]Grosenick and McGowan 1986.
[127]Álvarez-Berríos et al. 2013; Churches et al. 2012; White et al. 2013; and USAID 2016.

[128]Ghilardi et al. 2018: The authors concluded that "under a business-as-usual scenario, the simulated regenerative capacity of woody biomass is insufficient to meet Haiti's increasing demand for wood energy and, as a result, between 2017 and 2027 stocks of aboveground (woody) biomass could decline by 4% ± 1%" (Ghilardi et al. 2018, 1), and note that "simulations show that under a reasonable set of assumptions about woody biomass growth and harvest, Haiti will likely experience levels of fNRB (fraction of Non-Renewable Biomass) that are much lower than other assessments report. These results support recent analyses that argue for a less alarmist view of the relationship between deforestation and woodfuel demand in Haiti" (Ghilardi et al. 2018, 1, 6–7).
[129]Since agricultural clearing is the principal driver of deforestation in the current era, accessibility to agricultural markets incentivizes larger settlements and increased production.

the island, these roads were used by beasts of burden (Smucker et al. 1979, 55) capable of transporting charcoal to maritime wharfs on the coast. Soon, the price of transporting charcoal from the island was half the price of the transporting charcoal from the northwest to the capital (Smucker 1981, 30), and by 1986, transportation costs were comparable to those from Ganthier and Thomazeau in the Cul-de-sac plain due east of Port-au-Prince (McGowan 1986, 5). Elsewhere throughout rural Haiti, new road projects were initiated by local community councils or by missionary groups starting around the 1970s, financed by 'food for work' programs (Smucker et al. 1979). The USAID Agricultural Feeder Roads Project commenced in April 1976 and constructed 317 kilometers of new roads in Haiti by December 1982 (USAID 1983, 2).

Considering only the contributions from HACHO, USAID, and the additions to the island of La Gonâve, at least 1,200 new roads were established in Haiti from the late 1960s to the early 1980s. The addition these new roads, many built off of existing arterial highways initially established or shored up by U.S. Marines, opened up previously remote, inaccessible areas of Haiti to charcoal production and distribution.[130]

By 1985, charcoal production in Haiti was already considerably less concentrated.[131] When 148 charcoal producers from six different locations in Haiti were surveyed, only 56 percent responded they had been making charcoal in 1980, providing more evidence that charcoal truck drivers were going farther distances to collect charcoal (McGowan 1986, 14) as a reflection of the decentralizing effect of additional roads.

With the historical increase in roads, not just a few traditional and easily accessible areas of Haiti were targeted for intensive charcoal production. Original charcoal-producing zones were under less pressure than before, permitting their recovery from overexploitation of wood resources. New roads, decentralization of production, and the recovery of original areas contributed to the historical shift of major charcoal supply zones noted in this report, and to differential increases or decreases in the percentages supplied to the capital. Evidence for this causal explanation can be seen in the data collected for the present report:

Feeder Roads

Smaller feeder roads and departmental roads—analogous to tributaries of a river that eventually join the national highway system in Haiti—registered a volume of charcoal equivalent to approximately 30 percent of the amount consumed in Port-au-Prince during the same time. Many of these feeder roads and departmental roads are the very routes established since the 1960s discussed at length above.

Periphery Stations

A volume of charcoal equivalent to one-half the amount consumed in Port-au-Prince during both sampling periods was enumerated at the farthest, most remote enumeration stations from the capital, demonstrating that charcoal production occurs at high levels in the far reaches of the country. Such a phenomenon would be highly unlikely if a sufficient system of roads did not extend from these furthest periphery stations.

Changes in Transportation

The historical literature indicated that boats and trucks transport charcoal in similar quantities. Voltaire stated that transportation to Port-au-Prince from the Northwest (then supplying an estimated 50 percent of charcoal consumed in the capital) was equally shared between trucks and maritime vessels.[132] The research presented here shows that the volume of charcoal being transported by maritime routes appears to have diminished significantly, likely due to the addition, penetration, and improvement of road systems.[133]

The Rise of Charcoal Woodlots

Charcoal woodlots arose across Haiti in an historical response to deforestation, climatic drying, decreasing agricultural yields, and a large urban migration that increased demand for rurally produced charcoal.

The historical deforestation of Haiti has been well documented to have mainly occurred before the advent of charcoal production in that country, due to clearing for the plantation model of agricultural production

[130] Voltaire 1979; Smucker et al. 1979, 1981; Cohen 1984; Stevenson 1989.
[131] McGowan 1986, 14.

[132] Voltaire 1979, 8.
[133] Another possible explanation is that seasonal changes in offshore ocean currents dictate boat transportation.

during the colonial period, the lucrative timber extractive strategy of the colony, and subsequent timber concessions authorized by the new Haitian government to pay off a large war indemnity to France.[134] Some deforestation continued to occur through ongoing agricultural clearing, but the extent of forest cover that remained in Haiti when the charcoal trade roared to life in the 1920s is not well established.

Deforestation in Haiti not only resulted in the removal of hardwood trees; it also depleted many of the soil profiles necessary for the regeneration of original hardwood tree species. Deforestation rapidly accelerated a drying trend on the island of Hispaniola that began as early as the middle of the Holocene epoch (Higuera-Gundy et al. 1999). Few ecological zones now represent the original characteristics outlined by Holdridge in the life-zone classification system he created for Haiti,[135] which is still used as a standard forest classification system throughout the world.

The loss of forests and topsoil, and the subsequent exposure of underlying and more uniform soil profiles, coupled with ongoing climatic drying and less predictable season rains, has made the absence or presence of moisture the new *de facto* determinant of ecological zones in Haiti. This is most evident in the spread of *Prosopis juliflora*, an exotic tree species, well beyond the lower elevation zones where it initially established in Haiti; ongoing climatic drying increased the habitat of this and other drought-tolerant, invasive tree species. By 1991, the World Bank reported that natural *Prosopis juliflora* stands in Haiti dominate 'approximately 300,000 ha. of degraded, semiarid, public, and private forest land,'[136] or approximately 11 percent of the land surface of Haiti.

Thus, while most of Haiti's original hardwood forests and soil profiles are gone, much of the land is now covered by a combination of such trees and woody shrubs in a well-documented historical process starting as early as the late 1700s.[137] This rapid spread of trees and shrubs in Haiti is not only supported in the historical literature; it is also supported by fluctuations in arboreal pollen, weed types, and erosion from sediment cores in Haiti's largest freshwater lake. These lake sediment core analyses suggest a "temporary reestablishment of local forests and reduction of soil loss"[138] that correlates with land-use changes at the beginning of the 19th Century; after Haitian independence in 1804, large colonial plantations were destroyed and abandoned, and Haitians fanned out across the country and established smaller agricultural settlements, frequently at higher elevations. Brenner and Binford's research suggests that the correlated changes in sediment and pollen levels reflect this period history (1988).

The two exotic tree species that now dominate much of the rural landscape of Haiti (*Prosopis juliflora* and *Haematoxylum campechianum*) are highly adapted to poor soils, low moisture, and prolonged drought. These tree species are prolific seeders, propagate in a variety of novel ways, rapidly encroach into new territory, and are protected from foraging animals by thorny trunks and branches. *Prosopis juliflora* and *Haematoxylum campechianum* coppice aggressively when cut at the stump; while original hardwoods disappeared when cut, these rapidly spreading exotic trees continue to return through coppicing and permit their ongoing propagation across the landscape.

The first known mention of charcoal production in Haiti in the historical literature mentions only one tree, *Prosopis juliflora,* and notes that it is "used a great deal for fuel, some of it as charcoal."[139] Since around the middle of the 20th century, *Prosopis juliflora* has been named consistently as the tree most utilized for charcoal

[134] Bellande 2015; Tarter et al. 2016.
[135] Ehrlich et al. 1985.
[136] World Bank 1991, 86–87.

[137] de Saint-Mery 1797, 128–129; Wallez 1826, 72; Frankline 1828, 286; Mackenzie 1830, 39–40, 62, 199, 195; Johnson 1909, 648; Woodring et al. 1924, 57–59, 61, 63, 485; Gill 1931, 138–141; Wetmore and Swales 1931, 28; Klein 1945, 8; Curtis 1947, 3–4; Wood 1963, 14, 113; Palmer 1976: 29). See Hatzenberger 2000, Bellande 2015, and Tarter 2015a for extensive ecological histories documenting these changes to Haitian forests; and Tarter 2015a for a history of the rapid encroachment of *Prosopis juliflora* and *Haematoxylum campechianum* across Haiti, and their shaping by Haitian farmers into what would become the managed woodlots now supplying the vast majority of Haiti's charcoal needs.
[138] Brenner and Binford 1988, 94.
[139] Woodring et al. 1924, 63.

production in Haiti,[140] and *Haematoxylum campechianum* has consistently been named as the second-most utilized tree species for charcoal production.[141] Both of these tree species have been reported growing in association in multiple locations across Haiti since shortly after the Haitian revolution.[142]

These forces are likely acting in tandem with other influences—such as the increase in remittances sent to Haiti by the large diaspora abroad—that explain the high level of tree and shrub coverage in Haiti as one component of understanding how Haitians have continued to meet increasing charcoal demands over time. The other major answer to the question is attributable to Haitians themselves—namely the efforts of rural Haitian farmers to shift from a wood extraction paradigm toward a paradigm of wood management for energy needs, discussed subsequently.

The Sustainability of Haitian Charcoal Woodlot Systems

Social and Ecological Sustainability

Recent research has provided strong evidence that over time Haitian farmers slowly shifted from the practice of overextracting a range of natural arboreal regrowth on public land to the management of specific wood-energy tree species[143] (*Prosopis juliflora* and *Haematoxylum campechianum*) on private land. From a theoretical standpoint, Haiti is thus shifting from an energy extractive model of wood fuel procurement toward a domestication of energy model, first described and predicted by the anthropologist-architect of the largest and longest lasting national tree-planting project in Haiti.[144] This *in situ* phenomenon has led to the eventual rise in prominence of Haitian farmer-managed woodlots, which mitigate decreasing rural soil fertility and declining agricultural yields with increasing charcoal production to respond to growing urban demands.

From the standpoint of human needs, research suggests that management techniques within these woodlots represent the most labor-efficient, highest yielding, and animal resistant methods of wood cultivation for charcoal production.[145]

From an ecological standpoint, coppice woodlots dominated by a few invasive species and harvested every 3–7 years will never approach the ecological richness of the long-felled primordial forests and original life zones of Haiti and invariably results in an indeterminate level of land degradation. However, one major, unexpected result of the USAID-financed Agroforestry Outreach Project of the 1980s and 1990s was that many of the woodlots established through project-planted exotic trees created sufficient conditions for the natural regeneration of *native* tree species.[146] While further research is needed to determine if the present species composition of woodlots may offer the same ecological possibilities, at least two known interim ecological benefits occur from the widespread tree coverage of *Prosopis juliflora* and *Haematoxylum campechianum* trees across Haiti: the soil nitrogen-fixing quality of both trees, and the fact that woodlots provide more protection against the elements (sun, wind, and rain) for remaining topsoil than tilled agricultural plots or barren land.

Improving Existing Woodlot Systems

If Haitian farmer-managed charcoal woodlots are already balancing ecological needs and human needs as best as possible considering the unique case of Haiti, one of the most logical interventions to promote an increase in the volume of charcoal produced would be to graft different accessions from more productive varieties onto the trunks, stumps, or branches of existing tree species within the system.

The vast inter-species diversity, and diversity of intra-species genetic and morphological expressions of *Prosopis* point to an equally vast menu for cultivating ecologically, climatically, and socially appropriate woodlot trees in Haiti. The choice of accession would depend on the social needs and the environmental circumstances of different areas in Haiti.

[140] *Gayak* (*Guaiacum* spp.) was historically the preferred species for charcoal production throughout Haiti (Voltaire 1979; Smucker 1981; Murray 1981; Conway 1979), but the *gayak* tree grows very slowly (Francis 1993), which is likely the reason it did not persist to eventually become managed in woodlot systems. Voltaire claimed that *gayak* disappeared due to the 50-year period required for complete regeneration of the tree after cutting (1979, 9).
[141] See Tarter 2015a.
[142] Mackenzie 1830, 39–40, 62, 195, 199; Woodring 1924, 58–59, 61–63, 485.
[143] Tarter 2015a.
[144] Murray 1984, 1986, 1987, 1991.
[145] Tarter 2015a.
[146] Smucker and Timyan 1995.

As an illustrative example, both *Prosopis juliflora* and *Haematoxylum campechianum*, the most commonly used trees for charcoal production in Haiti, have thorns that protect the trees against browsing animals. However, Haitians also frequently mention these thorns as negative, dangerous aspects of harvesting wood and producing charcoal, despite the value the thorns provide by protecting trees from foraging animals. The grafting of a thornless, non-browsed accession could be a vast improvement to the labor and safety component of the Haitian coppice woodlot management system. In promising tests conducted in Haiti, thornless varieties of *Prosopis* from Peru that were grafted onto Haiti *Prosopis* trunks yielded some accessions that were not browsed by goats,[147] pointing to possibilities of improving some features of charcoal woodlot tree species without diminishing other valuable features.

There are also *Prosopis* species known for their ability to thrive in highly alkaline and saline soils.[148] The utilization of such *Prosopis* accessions in charcoal woodlots may be useful for charcoal production in certain highly degraded locations in Haiti that suffer from soil salinity, such as former plantation lowlands. Incorporation of such *Prosopis* would likely require new planting, because in this instance the grafting of new ascensions would unlikely result in the growth of alkaline and saline resistant root structures.

Some *Prosopis* species and varieties are highly valued for their seedpods, which represent important sources of protein and sugars for animals.[149] Humans have chewed or eaten *Prosopis* as early as 6,500 BC, and in times of severe need.[150] *Prosopis* was traditionally made into flour and bread in parts of South America, and in parts of India the pods are eaten as vegetables, and bark is mixed with flour in times of famine.[151] However, the pods of most *Prosopis* in Haiti are unpalatable,[152] pointing to yet another way in which tree improvement through grafting could lead to the possible cultivation of *Prosopis* in Haiti for both animal and human consumption. These options for varied improvement of woodlot trees may also be possible with the similar *Haematoxylum campechianum*, although the species has received less research and attention in the literature.

Finally, many of the woodlots that cover much of Haiti are in fact agroforestry systems. After harvesting a woodlot for charcoal, a farmer may procure two or three crop rotations before newly emerging coppice from trunks left carefully in place will form a low canopy, which will prevent further food crops from growing here until the next time charcoal is harvested. In this sense, the system may be viewed as a woodlot or as lengthy arboreal fallow period, which simultaneously provides for occasional charcoal production. These findings suggest that charcoal production at this point in Haiti's history is more of a solution than a problem to some of Haiti's economic and environmental challenges.

The continuity and growth of the charcoal trade in Haiti since the 1920s, the systems of woodlots and their sustainability factors, the passage of Hurricane Matthew as a test of the robustness of the system, and the possibilities for improving woodlot tree species for increased production, safety, and establishment in inhospitable soils all show that the charcoal production system in Haiti has value, is durable and sustainable, and cannot be discounted.[153] The economic and employment contributions of Haiti's charcoal production systems are highlighted in the context of policy implications in the closing chapter of this report.

[147] Lee et al. 1992.
[148] Pasiecznik et al. 2001.
[149] Pasiecznik et al. 2001.
[150] Fagg and Stewart 1994, 949.
[151] Ibid 950.

[152] Felker, personal communication.
[153] See subsequent section on the passage of Hurricane Matthew as a natural experiment that tested the robustness of these woodlot systems in an area of Haiti that produces large volumes of charcoal.

VII. Policy Implications

This study and the innovative charcoal rapid-assessment methodology present important new steps in growing efforts to understand the charcoal sector in Haiti. Indeed, the data shed additional light on this poorly understood commodity and its multifaceted and far-reaching impacts on Haiti's economy and environment. To help inform policy and programming in Haiti's environment, agriculture, and energy sectors, four key takeaways for Government of Haiti (GoH) policy makers, donors, and development organizations are discussed below.

The Charcoal Industry in the National Economy

The results of this study vividly underscore that, in Haiti, charcoal is big business. Based on initial calculations presented, charcoal is one of the largest on-farm- and natural resource–related value chains in the country. The total value of the Port-au-Prince charcoal market is approximately US$182 million per year, the national level is approximately US$392 million per year, at 4.7 percent of GDP.

These findings reinforce a growing body of research over the past several decades, which has repeatedly provided evidence of a large and increasing charcoal sector in varied parts of the country. Such conclusions should not be entirely surprising to careful observers of national trends within Haiti; the topic is frequently discussed, as evidenced in a recent article from the country's largest newspaper that references the 'millionaires of the charcoal trade'.[154] Rather, the conclusions support the anecdotal observations of many Haitians and add to the growing chorus of experts who have pointed to charcoal's importance.

[154]"Charbon de bois: qui sont les millionnaires de ce commerce?" *Le Nouvelliste,* April 17, 2018. Port-au-Prince. Accessed on August 25, 2018 at https://lenouvelliste.com/article/186177/charbon-de-bois-qui-sont-les-millionnaires-de-ce-commerce

The value of this sector in the context of the Haitian economy demands action. It is of such a magnitude that it should not be ignored in national policy considerations.

Implication of Charcoal Production Stigma on Policies

An inaccurate discourse and a persistent stigma surrounding charcoal impede rational policy making and investments in the sector. Despite the economic significance of charcoal noted in the previous section, over the previous five decades, the primary policy attention that charcoal has received has come in the form of unenforceable bans and uncollected tax levies. This phenomenon is attributable at least in part to the fact that much of the long-dominant discourse on charcoal is incomplete or inaccurate. The supposed original sin of charcoal production—its leading role in the loss of Haiti's primordial forests—has been conclusively rebutted but continues to capture the popular imagination as a compellingly simple (although inaccurate) explanation of a complex problem. Instead, an array of historical economic and political factors is now known to have been responsible for the vast majority of this original deforestation (Bellande, 2015). Similarly, despite oft-repeated forecasts of impending ecological disaster from ongoing charcoal production in Haiti and across the border in the Dominican Republic, a substantial body of research referenced throughout this report points to a charcoal industry that is more sustainably produced *within* Haiti and less tied to cross-border production in the Dominican Republic than commonly believed.

Nevertheless, charcoal's negative reputation continues to drive much of the policy debate surrounding the industry. Its stigmatization as a dirty, destructive, and informal sector fuel source tends to lead to unrealistic calls for controls on production, or for the prohibitively expensive replacement

of charcoal with other sources of cooking fuels. The result is skewed policy making that prevents the consistent, coordinated action necessary to capitalize on the economic, environmental, and energy policy opportunities offered by charcoal.

The positive aspects of the charcoal industry in Haiti include the ability of sustainably managed charcoal woodlots to provide much-needed sources of income as important contributors to rural economies, as ecological buffers in and around environmentally fragile zones and protected areas,[155] and as a key contributor to a greener and more independent national energy strategy. In the face of the dominant discourse prejudiced against charcoal, however, there are very few efforts to optimize the industry's true potential.

Equally unfortunate, this dearth of informed, pragmatic policy making also forestalls efforts to grapple with the very real problems that *are* attributable to charcoal. These include ongoing charcoal production in ecologically fragile areas (including mangroves and upland forests), ecological deterioration, and loss of woody biomass in unsustainably harvested zones, as well as the serious health impacts of household charcoal consumption. Yet all of these challenges could be pragmatically mitigated through improvements to charcoal in Haiti through solutions like woodlots, and improved charcoal kilns, etc.

Policy Designs Inhibited by a Lack of Data on Charcoal Sector

Even with the converging consensus of historical and recent research discussed above, policy makers, donors, and implementers are still plagued by a profound lack of detailed and up-to-date data on the highly dispersed and constantly evolving charcoal sector. These gaps in the existing knowledge base extend to all aspects of the charcoal industry, including: the characteristics of value chain and its many actors; price behaviors and trends; agronomic analyses of current wood energy production techniques by peasant farmers; measures of sustainability and the renewability of charcoal production under different conditions and in different settings; and consumption habits and preferences. Without these additional pieces of the puzzle, even with a newfound openness toward engaging in and improving the sector, effective policy making will remain elusive.

Interestingly, this absence of sufficient data is partly due to the general lack of human and financial resources in Haiti needed for better policy making and programming, regardless of the sector. But it is also intimately linked to the stigma surrounding charcoal, which has tended to reduce interest in and funding for research on the topic. Better data will hopefully have the follow-on effect of helping combat the unhelpful stigmas around the sector.

[155]See UNEP 2016 for a more detailed discussion of policy recommendations for use of woodlots to help protect mangroves and upland forests.

VIII. Areas of Additional Research

This study concludes with several key areas of additional work for policy makers, donors, and project implementers to consider in order to more adequately engage with the challenges and opportunities posed by charcoal and its central role in Haiti's society, environment, and economy.

Undertake Additional Research on Key Facets of the Charcoal Sector

In order to help guide future decisions regarding the sector, additional information is needed on several key fronts, including: economic and commercial dynamics, value chain mapping, agricultural practices, and ecological and sustainability considerations. A multi-organizational effort, in close coordination with the Government of Haiti (GoH), to systematically collect, organize, and disseminate this data would help fill existing knowledge gaps and verify or update knowledge from previous studies. Data gaps are listed below, grouped by sector.

Commercial and economic dynamics:

- Detailed analyses of each stage of the value chain—from charcoal producers (farmers and professional charcoal producers), to transporters wholesalers, retailers, and final consumers—in order to understand cost structures, inefficiencies, and market trends.
- Socioeconomic studies of the value chain participants, in terms of gender, poverty levels, and employment.
- Ongoing monitoring of wholesale and retail price variability—including an investigation of price drivers. This would allow for further exploration of several intriguing findings in the research above related to lack of price impacts of Hurricane Matthew, and for predictions about the effects of future tropical storms.
- Exploration of up-to-date household fuel consumption habits, including comparisons of frequency of use of large sacks versus *mamits* of charcoal.

Transportation trends:

- Since the present research identified a decline in maritime routes, further research into truck routes[156] is merited.
- The present research also identified a second wharf of comparable size to the Malpasse Wharf, on the Dominican side of Lake Azuéi (Saumâtre in the D.R.) (*see Figure 20 in main body of this report*). Future research could determine if and how much charcoal makes passage over this second wharf into Haiti.

Agricultural practices:

- Examination of recent innovations by farmers in the management of charcoal woodlots, and the intercropping of wood energy and food species (agroforestry systems).[157]
- Agronomic research on different genetic varieties of endemic or original and imported tree and shrub species that are most suitable for expanded wood energy cultivation.
- Research on the gendered division of labor and the gendered health effects around charcoal production, transportation, marketing, and consumption.

[156] For example, authors of the report are currently developing a methodology using cell phone GPS data to track exact tributaries of the entire charcoal transportation network.

[157] See Tarter 2015a as an example of a year-long study on these topics, in one area of Haiti.

Ecological impacts and prospects for sustainability:

- Examination of prospects for long-term sustainability of different charcoal cultivation and harvest methods, in terms of soil nutrients and ground cover.
- Acknowledge the serious health impacts of household charcoal use, and investigate cleaner stoves and cooking practices using charcoal, which would be both economically feasible and culturally acceptable within the Haitian context.

Armed with these refined and up-to-date data, the government and its partners could undertake more nuanced analyses, leading to better-informed policies and high-impact, evidence-based investments in the sector.

Fortuitously, two subsequent studies funded by the U.S. Forest Service (USFS) to inform the U.S. Agency for International Development may help fill some of these gaps and resolve lingering questions concerning the research presented here.

- The first study, currently under way, will repeat the same overall methodology presented in this report, using Cap Haïtien, located in the north of Haiti, as the core city. This new study will determine how Cap Haïtien is differentially supplied with charcoal from various locations in the north, and what, if any, additional volumes of charcoal are coming over from the Dominican Republic. The Cap Haïtian study will likewise employ the methodology applied in this study of extrapolating to other cities in Haiti, using a tons-to-population ratio that is based on *counts* rather than on *consumption* rates. Finally, the counts from the core of Cap Haïtien will test the accuracy of the tons-to-population ratio used in this study, when applied specifically to the population of Cap Haïtien; likewise, the Cap Haïtien data can be used to test the accuracy of predicting the Port-au-Prince figures. Since the Cap Haïtien replication will also sample in low and high seasons over similar weeks, it will provide additional datasets to add to those at hand, providing the first complete, nationwide dataset on charcoal flows in Haiti.
- A second study through the USFS is a remote-sensing analysis along the Haiti-Dominican Republic border, possibly supplemented with surveys concerning cross-border charcoal transport. The study is still in the research design phase. These studies, alongside the research presented in this report, will provide conclusive findings to answer the five research questions posed herein—*for now*. For as this research has demonstrated, the regions supplying charcoal to Port-au-Prince have shifted before, and may do so again; likewise, events such as the earthquake, hurricanes, and embargoes are likely to affect the charcoal sector in the future.

Undertake Additional Work in the Policy Space

Additional work is needed to assess and map the charcoal policy space. Currently, oversight of the sector is fragmented across a number of different GoH institutions. The lack of policy coordination in the charcoal sector has serious consequences, including the absence of a recognized forum for sharing of *lessons learned*, and little space for debate and coordination on institutional and policy questions. The resulting government policy confusion is reflected in misaligned donor and nongovernmental organization (NGO) programming, which all too often dismisses or misunderstands the key role that charcoal plays in the communities and economies that they seek to support. As a next step, work should be undertaken to fully map the policy space, benchmark against other countries, and develop a series of recommendations for the government of Haiti.

Haiti's development partners could support additional research, policy coordination, and on-the-ground programming to facilitate the paradigm shift already under way.

The methodology presented in the body of this research report could be replicated and tailored to benefit other countries where informal charcoal trade predominates. The lessons learned from research, pilots, and programming related to charcoal in Haiti could provide a roadmap for countries in similar situations. It is hoped that this report will benefit the people of Haiti and those of other countries for whom the charcoal sector is a vital component of their livelihoods and lived reality.

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X. Annexes

Annex 1—Fieldwork Timeframe Phases

Fieldwork was planned in three sequential phases:

Phase I—Preliminary Studies (2016–2017):

- Identify and visit important urban charcoal receiving and wholesale locations in the capital:
  - Conduct contextual interviews;
  - Develop typology of charcoal transport trucks; and
  - Repeat weighing of charcoal bags to establish average vehicle weights per category in the tripartite truck typology.
- Identify and visit maritime wharfs in/around the capital:
  - Conduct contextual interviews;
  - Develop typology of charcoal transport boats; and
  - Repeat weighing of charcoal bags to establish average vessel weights per category in boat typology.
- Scouting trips to five regional areas:
  - Conduct contextual interviews;
  - Affirm appropriate location of roadside enumeration stations;
  - Establish room-and-board arrangements near enumeration stations for week-long stays by enumeration teams; and
  - Address security concerns at each station by meeting with the local *kazèk* (magistrate).

After the completion of Phase I and the day before the commencement of Phase II (planned for early September 2016), the initial firm that was contracted to collect data pulled out of the study, citing lack of capacity. Phase III (planned for October of 2016) was disrupted by the passage of Hurricane Matthew.[158] *Missing the major high and low charcoal production seasons in 2016, the research was delayed until 2017, which also permitted the stabilization of charcoal markets after the hurricane.*

[158]See Tarter et al. 2018.

Phase II—High Season Sampling (August 2017):

- Entire enumeration team meeting:
  - Establish teams for each zone; and
  - Train enumerators in research protocol and safety protocol.
- Sampling

Due to a counting error made by the newly contracted firm, enumerators were sent home one day early during the first sampling period. To compensate for hours missed during Phase II, a third sampling period of 67 hours (Phase IV) was added to the research design.

Phase III—Low Season Sampling (October 2017):

- Entire enumeration team meeting:
  - Review/revise teams for each zone; and
  - Review research and safety protocol.
- Sampling

Phase IV—Addendum High Season Sampling (December 2017):

- Entire enumeration team meeting:
  - Review/revise teams for each zone; and
  - Review research and safety protocol.
- Sampling

Annex 2—Logistical Details about the Survey

Enumerator Workshop and Training

Prior to deploying enumeration teams to the field, the Research Team Leader (fifth author) facilitated a one-day training in Port-au-Prince that provided an overview of the study rationale, methodology, location of the enumeration stations, a survey schedule, and communication and security plans.

A major component of the training was to describe the survey methodology. Enumerators learned about the different types of transportation mediums (including the categories of trucks and boats) that they would be counting. The training used photos to provide examples of the different kinds of trucks the enumerators should look for and how to classify them using the tripartite typology.

Enumerators also learned about the different types of enumeration stations (e.g., intersections, principal roads, and wharfs) to be used in the study. At intersections, enumerators were instructed to record the type of vehicle, the direction it was traveling from, and the time of the observation. On the principal roads and intersections, the enumerators had only to record the category of the truck and time of passage. At wharfs, enumerators counted both the number of charcoal bags coming into the port off boats and recorded where the boats originated. Enumerators also recorded the type of truck and direction of travel for trucks leaving wharfs full of charcoal. Each enumeration station was assigned a team of three enumerators. All night shifts were required to have two enumerators present as a security measure. Wharf teams only did day shifts because all the wharfs close at night.

The training emphasized the idea that this was a team activity rather than an individual activity. In order for stations to be successful, each person had to participate and follow the cooperatively developed schedules to meet the data collection requirements.

Given the large geographic scope of the study, the research team wanted to have a system in place to ensure accountability (e.g., people are at their stations at the required times), reliability (enumerators are properly classifying trucks), and data backup (classifications matched with time stamps based on locations).

Logic for, and Creation of, Enumerator 'WhatsApp' Groups

Given the large geographic scope of the study, the research team wanted to have a system in place to ensure accountability (e.g., people are at their stations at the required times), reliability (enumerators are properly classifying trucks), and data backup (classifications matched with time stamps based on locations). Thus, each group was also asked to select a group name for pre-created 'WhatsApp'[159] groups. All enumerators were added to two different WhatsApp groups, which served different functions:

Group 1

The first group was used to track work shifts. Whenever someone started their shift, the team had to send a text that confirmed who was coming on-shift and who was going off-shift. The required message format was as follows:

Kenson + Richard + (James)—Pa Gade Solèy/JER
James + (Richard + Kenson)—Pa Gade Solèy/JER

In the above example, the text provides the name of the three team members. The person(s) whose name(s) appears in parenthesis are off-duty, while the other person(s) are on-duty. The team name appears after their names (Pa Gade Soley) followed by the specific enumeration station (JER, or Jérémie). WhatsApp adds time stamps automatically.

Group 2

Enumerators utilized the second WhatsApp group to post pictures of every truck that passed during daylight hours. No photographs were taken during nighttime hours due to security concerns (blinding drivers with flash, identifying enumerator locations, etc.).

Sharing photographs of trucks with all enumerators alerted the next station down the line that a truck should be coming and facilitated tracking trucks from one station to the next. This group chat was also used to disseminate any pertinent information that should be shared with the larger team (e.g., weather conditions, security concerns, etc.). The format of each text would include the picture, location of origin, size, followed by the specific enumerator team name, and station (e.g., Large/RD 102/Pa Gade Solèy/JER). WhatsApp adds time stamps automatically.

[159]WhatsApp is the most popular and widely used, free, chat application for phones in the world. It allows users to share messages and images, and time stamps both.

The WhatsApp groups had the added benefit of promoting coordination and communication among enumerations teams, fostering a spirit of healthy competition, and boosting overall morale.

Field Visits

The Research Team Leader (fifth author) made a series of surprise enumeration site visits, taking a team photograph with people present at the station and posting it to the WhatsApp group. This provided motivation for teams to stay engaged and at their station in case they would receive a surprise visit. It also turned into a fun, team-building activity. People did not know when or where the Research Team Leader would show up and would try to track or anticipate his sporadic movements.

Each enumeration station received at least one surprise site visit during the course of the study, although this was not achieved in one sampling period alone. None of the field visits were announced to the enumerator teams ahead of time to promote accountability/engagement. Given the geographic scope of the study, JP/HRO provided two interns who also conducted more frequent field visits to the core stations controlling the entrance of charcoal to Port-au-Prince. This helped to alleviate the workload/travel burden of the Research Team Leader.

There were several sites where no or very few trucks passed, which caused some frustration for these enumeration teams. These sites were along the border with the Dominican Republic (e.g., Cerca la Source, Belladère, Anse-à-Pitres, Kenscoff). The Research Team Leader visited all of these sites to talk to the team members and to explain to them that noting the *absence* of passing trucks is a form of data, and not to feel discouraged.

Security Issues

There were no major security incidents during the study period, although some enumerators raised concerns about safety during night shifts. Every team was provided a letter of introduction to take to the local police station upon their initial arrival, to ensure that authorities were aware of the study and knew about the work the teams would be conducting, particularly during the night. Teams also exchanged phone numbers with police officers to have a local emergency contact.

In addition, each team engaged two local motorcycle taxi drivers (e.g., prepaying services for the week) to have on call for transportation in case of emergency or to facilitate travel to/from the enumeration station and nearby hotels.

Other precautions included requiring two people on night shifts and utilizing WhatsApp group chats at night. When possible, enumeration stations were in proximity to police stations and some teams were actually able to conduct night shifts within the boundaries of roadside police stations. In places where police stations were not conveniently located, the enumerators would arrange to work from the front porch or rooftop of a private home during the nighttime hours.

One of the wharfs (Wharf Jérémie, located in Port-au-Prince) was flagged as a potential security risk due to its proximity to Cité Soleil, an area notorious for previous gang and kidnapping activity.[160] The Research Team Leader visited the team there and made contact with local gang leaders to introduce the study and explain who would be working there. None of the team members had any issues at the wharf after this introduction and communication with the local gang leaders.

Adaptations in the Field

The Morne Cabrit station had an unforeseen security concern. Multiple crimes had previously been reported at that intersection, and when the team presented their letter of introduction to the local police, the police strongly recommended that the team not conduct night shifts at the site. Once this concern was raised, the Research Team Leader traveled to the station to assess the situation. As a compromise, the night shift location was moved to the police station some 500 yards from the intersection. The Research Team Leader confirmed that the alternate night location still permitted the team to record the same data from the intersection (truck categories and origin).

[160] Reports differ on the current state of security in and around Cité Soleil.

Annex 3—Possible Sources of Errors and Adopted Mitigation Measures

The following list includes known potential sources of error and explains the steps taken to mitigate these possibilities:

- Enumeration stations were placed on the wrong roads, intersections and/or wharfs:

  Phase I of the research (see above) was explicitly designed to visit all areas of the country that would be surveyed, and through observations and contextual interviews with a range of different individuals, to properly identify through observations and contextual interviews with a range of different individuals, which roads, intersections, and wharfs were the most-utilized by charcoal transporters within Haiti and across the border from the Dominican Republic.[161] *The possibility exists that routes and ports shifted in the period of time between Phase I and data collection, but this is unlikely, as new roads and new port are detectable by satellite imagery.*

- Enumerator falls asleep;
- Enumerator misses a truck;
- Enumerator fabricates counts; and/or
- Enumerator abandons the station.

  These possible sources of error were mitigated in multiple ways that address each concern. First, all stations were overseen by three different enumerators, 24-hours per day,[162] *reducing the likelihood of any individual enumerator errors occurring. Second, all enumerators were instructed to take pictures of passing vehicles with their phones, and to share the photographs (using the WhatsApp Groups described above) with all the other enumerators, which served as a cross-check for the above concerns. Third, the Research Team Leader (fourth author of this report) had daily, periodic phone check-ins, and executed ongoing surprise visits to the enumeration stations, to ensure they were being properly managed as instructed during the training period discussed above. Not one enumerator abandoned station during any of the three sampling periods.*

- Data entry error:

  Data were cross-checked with original enumeration sheets as well as through the WhatsApp Group photos—which record the date and time of the event. In some instances enumerators improperly noted 'pm' after midnight had passed, but this is an easily recognizable and correctable error. In the few instances where data were missing, we returned to the sheets to see if the issue was one of transcription. If not, the mode value (small, medium, or large) for a given area during the same sampling period, day and time was applied. In the few instances at intersections where enumerators failed to record the direction of a truck's origin, the ratio for the given intersection was applied randomly to any missing values. Such instances occurred only a handful of times across all data sets from the three different sampling periods.

- Political unrest or extreme weather events disrupt charcoal transportation flows:

  The first firm contracted in 2016 pulled out due to a lack of capacity to execute the study. When we tried in October to sample, we were delayed due to the passage of Hurricane Matthew. However, there were no political unrest or extreme weather events during any of the three sampling periods of 2017.

- Skewing of numbers by the passage of Hurricane Matthew:

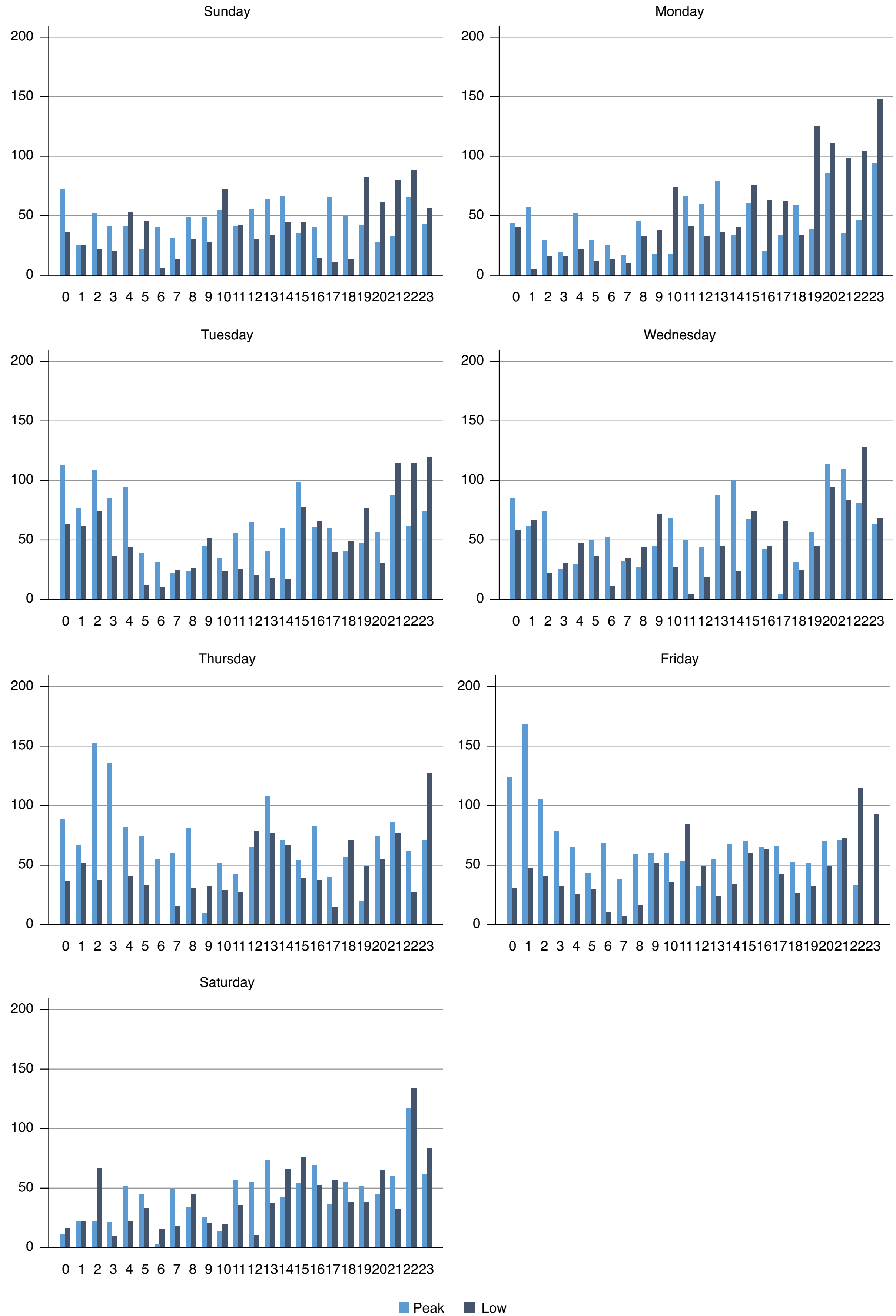
  This represents the largest potential source of error in the data set, but it is mitigated in four ways. First, the figures coming out of the southern peninsula can be cross-checked in reference to figures from the United Nations Environment Program's charcoal surveys conducted in the same areas affected by the hurricane, just before the passage of the storm (UNEP 2016). Second, the percentage of charcoal coming out of the southern peninsula can be cross-checked with percentages reported since 1985, controlling for gradual increases over time. Third, ten months had passed after the hurricane before and before the first sampling period, which allowed the charcoal market to stabilize. Finally, arboreal changes to the area where Hurricane Matthew passed were detailed extensively through separate World Bank research (See Box 1 in main body of report and Annex 5). These efforts all represent opportunities to catch and control for any spike or decline in charcoal production from the South since the passage of Hurricane Matthew.

[161]While charcoal entrance into Port-au-Prince used to occur by donkey transport as well, those days have ended with the introduction of motorcycles. Donkeys are still used in rural areas with poor access to major transportation routes, but they debark charcoal at locations where motorcycles or trucks arrive, rather than make the trip into Port-au-Prince. Likewise, motorcycles transport charcoal to/from truck loading locations, but not directly into Port-au-Prince as a primary mode of transportation

[162]Except wharfs, which close at night since boats do not dock or unload in the dark.

Annex 4—Complementary Analysis

FIGURE 22: Hourly Flows of Charcoal Entering PaP, Day by Day



Annex 5—Post-Hurricane Matthew Arboreal Assessment

In 2015 Hurricane Matthew passed over Haiti, creating widespread damage and thrusting an estimated 800,000 to 1.55 million Haitians in a state of food insecurity, with approximately 280,000 categorized as severely food-insecure. The storm adversely affected crops, trees, and physical infrastructure. An estimated two out of three farmers lost approximately 75 percent of their animal livestock (FAO 2017; UN World Food Program 2017). Agricultural damage assessments ranged from $573.5 million (the Haitian Ministry of Planning and External Cooperation) to $604 million (the Haitian Ministry of Agriculture, World Bank, and FAO) (FAO 2017). Total damages from the storm, from an estimation based on Haiti's 2015 GDP, were reported from to 2.8 billion USD (approximately one-third of Haiti's GNP) (World Bank et al. 2017) to $8.88 billion[163] (suggesting that Matthew destroyed the equivalent of 11.4 percent of the country's total production of goods and services).

The Haitian government-led *Damage and Loss Assessment* (DALA) conducted immediately following the storm used satellite imagery, interviews, and key conversations to determine losses across the country. In the agriculture sector, calculations included estimations of the value of crops lost, as well as damaged and lost trees. It was clear from this analysis that Hurricane Matthew's passage over the southern Tiburon Peninsula resulted in massive damage to arboreal systems, including: Haiti's remaining forests; fragmented tree stands; and a multitude of individual trees found on farms, in courtyards, on steep slopes, in deep ravines, along riverbanks, delineating property boundaries, lining roadsides, and in other isolated locations. The storm's damage to trees ranged from complete felling, snapping of trunks at various heights, snapped branches, and partial or total loss of foliage. However, it proved difficult to decipher satellite imagery for damaged, broken trees or standing dead trees versus standing live trees, and due to this, the full impact of the storm on tree resources was not fully known.

As such, the World Bank team undertook a Post-Hurricane Matthew arboreal assessment of the Grand Anse and Sud Departments (composing the lion's share of an area colloquially referred to as the 'Grand Sud') of Haiti—the areas hardest hit by the storm.[164] The study was conducted approximately ten months and two agricultural seasons after the passage of Hurricane Matthew. The time passed since the phenomena of interest permitted trees to recover, ensured that answers to questions more accurately reflected final outcomes for trees, permitted tree-based markets to stabilize, and allowed for a better understanding of how farmers used newly opened lands in the subsequent agricultural season.

The pertinent conclusions of the full report are summarized below, and are derived from the combined findings of land-based transects (n=298) and tree surveys (n=1,682) administered by a research team that visited six different locations along the broad path of Hurricane Matthew (see Figure 23). The transects were designed to directly observe the species and quantities of trees that fell or were damaged during the hurricane, and to discover what farmers did with such trees (green points, Figure 23). The surveys were targeted toward individuals in urban or peri-urban areas that directly observed the processing, marketing, and transportation of trees, charcoal, and planks in volumes far surpassing those of more isolated rural landowners (blue points, Figure 23).

The main results of the study demonstrate the types of trees fallen across the sample region and the uses of these trees by farmers, with strong implications for the charcoal market. Fallen coconut, breadfruit, and mango trees together represented 52 percent of all of the fallen trees. Farmers who owned the plots of land where sample transects took place were asked about their primary use of trees knocked over during the storm. Across the samples from all regions, Haitian farmers overwhelmingly produced charcoal from trees felled during Hurricane Matthew.

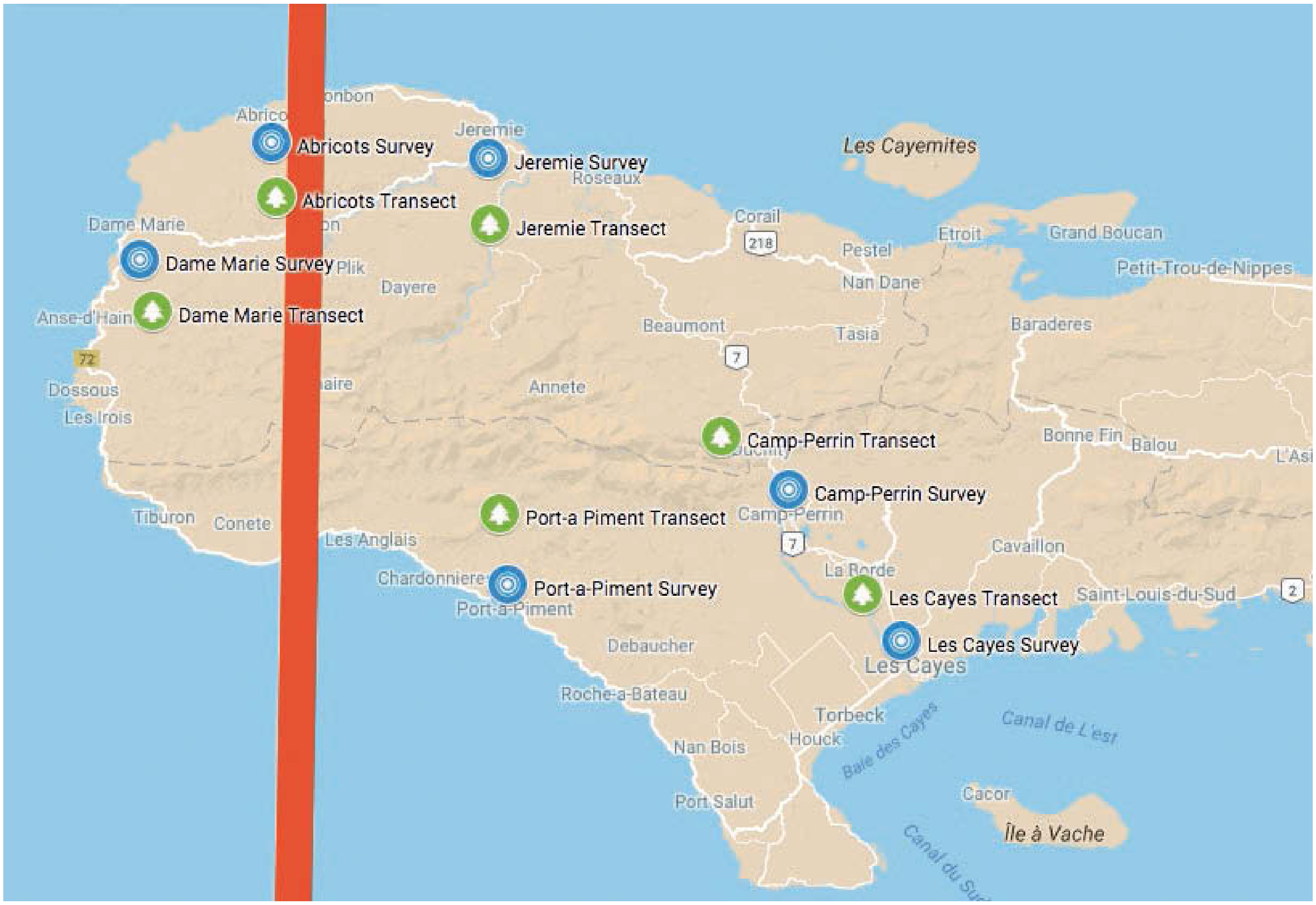
Some 14 percent of respondents from transects across all regions (see Figure 23) indicated they let fallen trees remain where they were, 6 percent transformed their fallen trees into planks, and only 1 percent used their fallen trees for construction purposes (Figure 24).

The research showed that the number of bags of charcoal produced by landowners sampled in transects ranged widely, with a 15,724 bag total from 261 responding landowners, an

[163]http://www.businessinsider.com/haiti-hurricane-matthew-economic-impact-2016-10

[164]Other areas that were indirectly impacted include the Nippes department, the large offshore island of La Gonâve, the southwestern and northwestern portions of the Artibonite department, and the Nord-Ouest department.

FIGURE 23: Approximate Locations of Transects and Surveys Relative to the Path of Matthew



The red line represents the pathway of Hurricane Matthew.

FIGURE 24: Primary Use of Downed Trees across All Regions

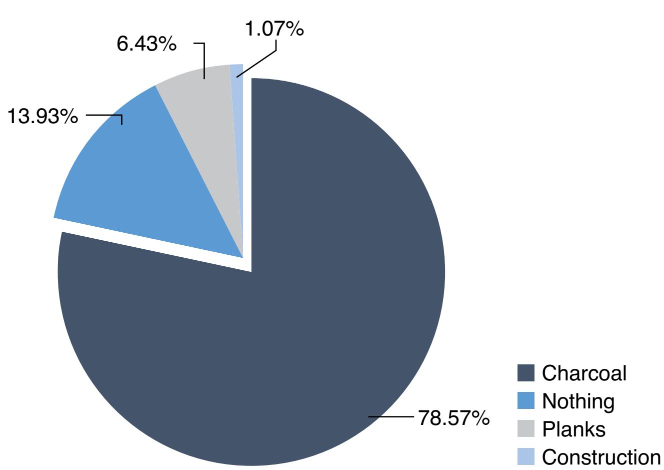
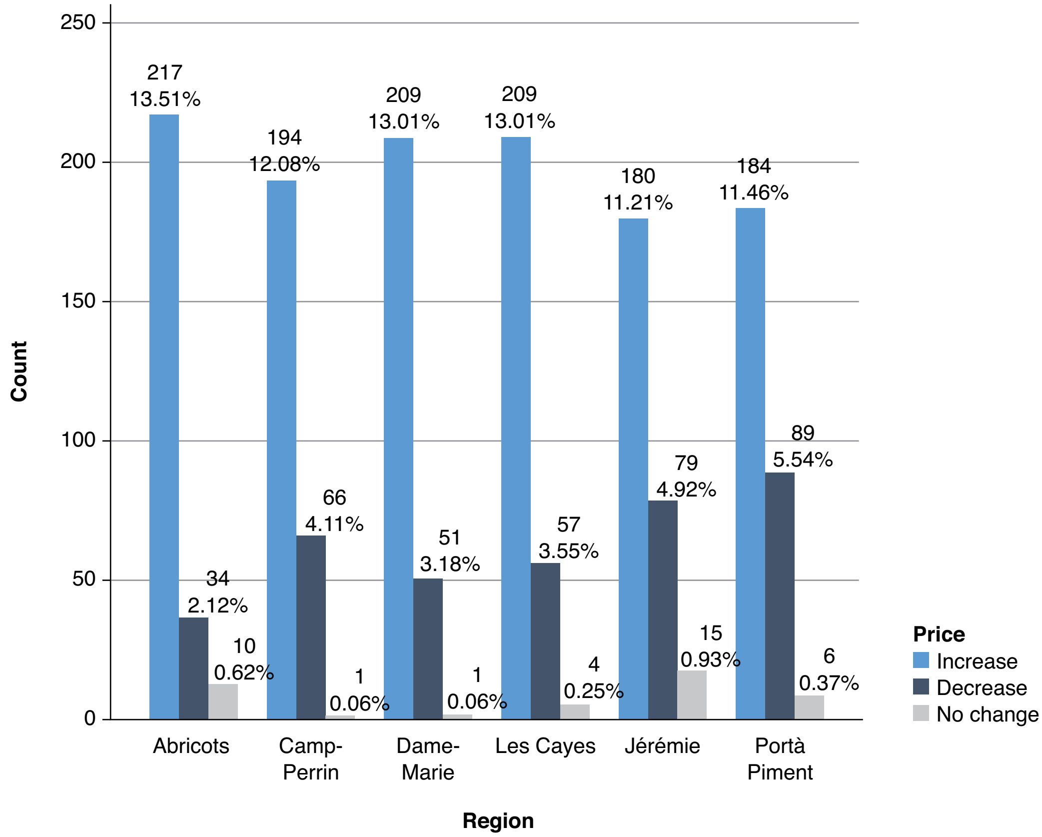


FIGURE 25: Changes to the Price of Charcoal



average of approximately sixty bags per transect, with four different landowners reportedly producing approximately half of all the charcoal bags across all samples.

With an influx of charcoal in the market, the widespread hypothesis was that prices of charcoal would fall. This research demonstrated otherwise. Across all samples, 74.28 percent responded that the price had increased since the passage of Hurricane Matthew (Figure 25). The majority of respondents in each region also responded, although there were very slight regional differences.

Across all samples, whether considering the *mode* or the *mean*, the price for a large sack of charcoal increased by 80–100 Haitian Gourdes (~1.25–1.55 USD) after the passage of the storm (Figure 26).

The mode price for charcoal in the most remote locations (Dame-Marie and Abricots) was the lowest before and after the storm; conversely, those locations closest to the national highway (Les Cayes and nearby Camp-Perrin) had the highest before and after prices. Jérémie, with a well-established albeit slower maritime route to Port-au-Prince, occupies the middle of this range. These findings suggest that transportation costs to Port-au-Prince dictates charcoal prices.

When asked about a post-hurricane correction of market prices, the vast majority of respondents across the samples (92.82%) believed the price of charcoal would continue to rise, while a small minority believed prices would return to pre-hurricane prices (6.56%), and even fewer still believed that prices would remain at their current rates (0.62%). When survey respondents were asked *why* they thought the price of charcoal would continue to rise, many concluded that prices would be dictated by supply—trees were significantly diminished in the area as a result of the hurricane.

Respondents reported that charcoal trucks came more frequently to the Grand Sud region after the passage of Hurricane Matthew, likely a prospective response to an increase in supply. Across all samples, 62.33 percent of respondents indicated charcoal trucks came *more* frequently; 32.23 percent reported that trucks came *less* frequently; and 5.45 percent responded that trucks came with the same frequency as before the storm (Figure 27).

FIGURE 26: Mode Price Change for Large Sack of Charcoal

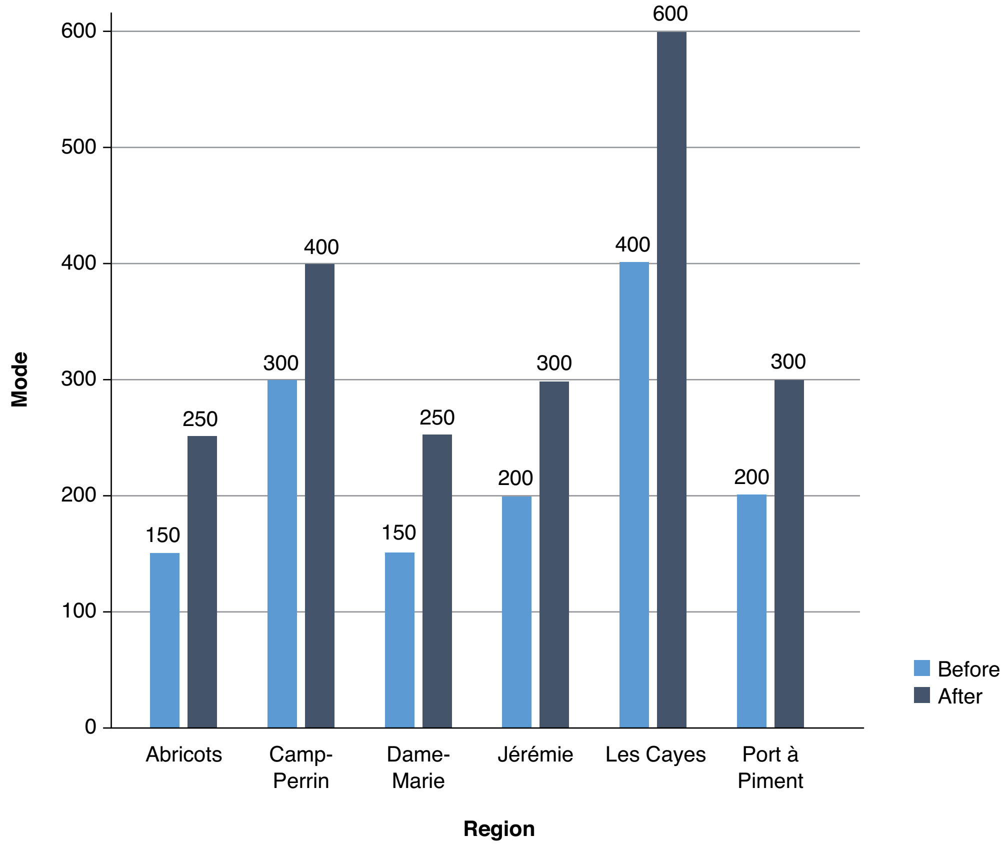
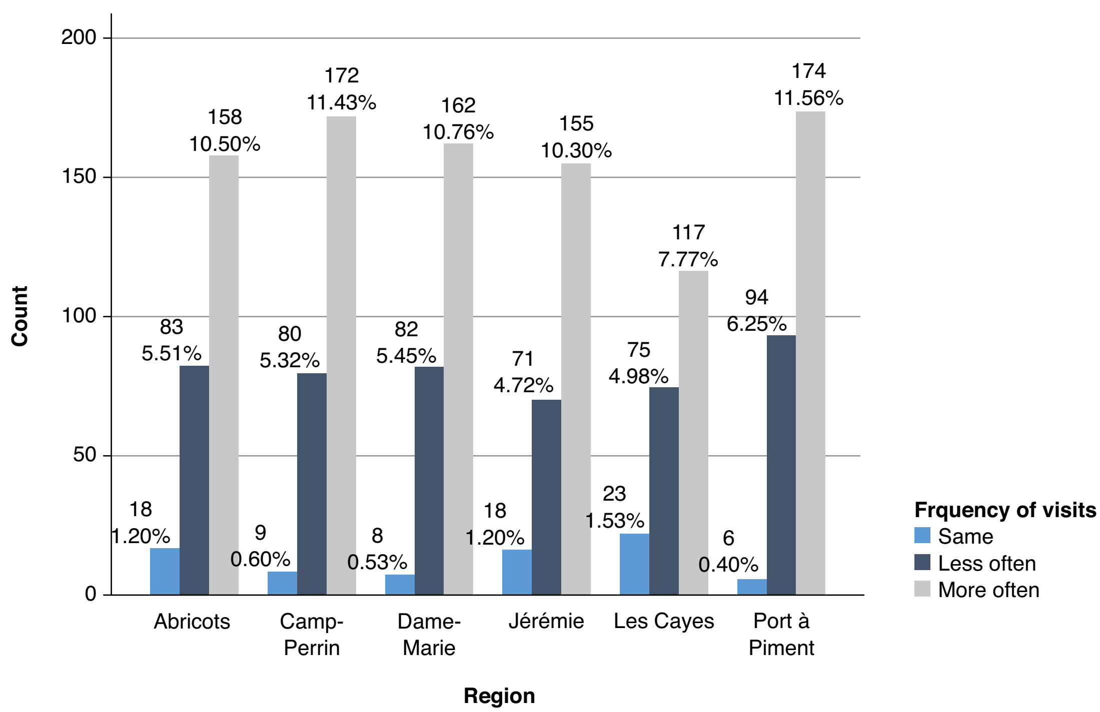


FIGURE 27: Frequency of Charcoal Truck Visits after Hurricane Matthew



These results can be interpreted by considering demand for charcoal, planks, and construction. Urban demand for charcoal in Haiti is high and constant, the demand for lumber is lower on both counts. While lumber fetches a higher price as a wood-derived product, it often does not sell quickly, thus even those farmers that may have been able to pay plank sawyers up front, nevertheless hedged their bets on charcoal, given their need for immediate cash after the storm. That many people reported a lack of capital to pay plank sawyers suggests that remuneration is requested immediately by sawyers, rather than sought out after planks eventually sell, providing further evidence of a lower overall market demand for planks. The opposite is sometimes true of charcoal—some participants in the charcoal value chain may not be remunerated until charcoal is finally purchased.

One possible explanation emerges for the anomalous post-hurricane increase in charcoal prices commensurate with an increase in charcoal production. Charcoal trucks came more frequently to the Grand Sud region after the passage of Hurricane Matthew—perhaps an initial response by prospective purchasers to an increase in supply. Across all samples, 62.33 percent of respondents indicated charcoal trucks came *more* frequently after the storm. An initial increase in charcoal trucks may have precipitated a jump in the commodity price, or sparked a gold rush for charcoal.

Annex 6—The Gendered Aspects of Charcoal Production

Historically, women and children were responsible for the collection of firewood for rural, domestic consumption in Haiti (Murray and Alvarez 1973). While the conclusions from the most comprehensive review on the gendered aspects of charcoal production in Haiti is dated, it remains remarkably accurate some 40 years later:

> Charcoal production overall is not considered to be a woman's occupation, but women are sometimes involved to varying degrees. In areas of greater concentration of charcoal production, women tend to be more extensively involved; poorer women are more active in charcoal making than those better off. Women rarely make charcoal independently of men. Where men and women work jointly at charcoal making, women's activities are usually centered around raking out coals and sacking charcoal. Men predominate in the wholesaling of charcoal although some women are active wholesalers. Retail sale of charcoal is handled almost exclusively by women (J. Smucker 1981, 35).

Increased women's participation in charcoal production in the area east of Port-au-Prince was noted as a deviation from an historical norm (Conway 1979, 13–14), but it is not clear whether this deviation was widespread or continued as a trend. Most recent research presents a gendered division of labor around charcoal production and consumption in a manner similarly described above.

Beyond the gendered division of *labor* related to charcoal production and consumption, there are also differential *health* concerns affecting women, men, and children. While charcoal produces less smoke than traditional firewood, women and children are still disproportionately and adversely affected by smoke during the preparation of meals with charcoal (Murray and Alvarez 1973). Men are typically more adversely affected by smoke and the inhalation of charcoal particulate matter during the kilning, coal raking, and bagging tasks of charcoal production. Men are also more subject to inhaling harmful charcoal particulate matter during the transport of charcoal from rural to urban areas, while women are subject to the same dangers at presumably higher levels during charcoal retailing in urban areas.

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