The Economics of Smallholder Households in Central Haiti

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ABSTRACT

Smallholder households in Haiti face many natural resource management challenges. Agricultural production occurs on deforested hillsides prone to erosion. Charcoal is in an important source of income, and woodfuel stocks are often over-exploited. Donor-funded projects and non-governmental organizations have made large investments in programs that promote soil conservation practices and reforestation. Despite the magnitude of the problems and the amount invested, there are relatively few economic analyses of the long-term adoption of soil conservation practices and woodfuel management. This dissertation uses an economics approach to examine the adoption of conservation practices and the management of woodfuel resources in Central Haiti using cross-sectional data covering 600 households. The results show that plot and household characteristics have different effects on adoption across different classes of soil practices, particularly with regard to perceived soil quality, market access, and household health status. The results also provide evidence of the management of charcoal woodfuel stocks on private land. These findings inform the design and targeting of new programs related to soil conservation and reforestation in Haiti and other developing countries.

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CHAPTER 1

INTRODUCTION

Approximately 2.5 billion people in developing countries depend directly on agriculture for their livelihood. Around 1.5 billion within this group live in smallholder households, and in some countries they produce as much as 80% of national food consumption. Smallholder households also make up the two-thirds of the world's population that lives in poverty (Arias et al. 2013). In Haiti, smallholder households take on a similar profile. Out of a total population of approximately 11 million, the vast majority of the 5.5 million who live in rural areas belong to smallholder households. They also represent a large portion of those living in poverty and face an array of development challenges related to health, education, human rights, and environmental sustainability. Clearly, a complete understanding of the smallholder household is vital in poverty reduction and development.

The smallholder in Haiti is characterized as an agricultural operation with a relatively limited endowment of land and other productive resources. It is also sometimes defined by the use of predominantly family labor. While smallholders can be solely commercial operations, production for household subsidence is a common and important characteristic, especially in the developing world (Nagayets 2005). In Haiti, many smallholders sell a significant portion of their harvest on the open market while retaining some for consumption within the household. Smallholder agricultural production in Haiti, as in many poor countries, relies on little mechanization and is sometimes referred to as "low input, low output."

Natural resource management is central to many of the challenges faced by smallholder households in Haiti. The mountainous Haitian landscape was once almost entirely covered with forests, but centuries of overexploitation of its forest resources have left only 3.6% of the land covered by forest canopy (FAO 2014). Deforestation has led to the degradation of soil resources. The historical causes of deforestation and the subsequent high rates of erosion are complex; however, agriculture and charcoal production are principal factors. Unsustainable agricultural practices and an environmentally damaging charcoal industry continue to be major challenges in Haiti. They create huge environmental problems, while at the same time, represent the livelihood strategies that millions of smallholders rely on for survival.

While there are relatively productive alluvial plains and other flat land used for agriculture, the typical Haitian smallholder is limited to cultivation on sloped or highly sloped hillsides that are unsuitable for agriculture. A given household may manage two or three plots, totaling a little over a hectare of land. In response to the challenges of hillside agriculture, many use some form of conservation practice to manage soil resources. Among the soil and water conservation practices commonly found in Haiti are those that utilize living organic materials and those that utilize inorganic materials. Hundreds of millions of dollars have been spent by international development organizations to establish effective soil and water conservation practices. However, the efforts of smallholder and outside interventions have been largely insufficient to halt the continued soil degradation. With limited resources and no clear solutions, smallholders have to make difficult decisions on soil conservation.

Smallholder households in Haiti and other developing countries often can not rely on agricultural revenues alone. Off-farm employment and financial contributions from outside family members play an important role. In Haiti, charcoal production and the sale of agroforestry products are common livelihood strategies. Decisions related to the management of woodfuel supplies and agroforestry resources are components of the set of interrelated natural resource management decisions that a typical household makes. Similar to soil conservation, smallholder choices for these livelihood strategies have major implications for their welfare, the broader economy, and the environment.

This dissertation examines the ways in which households manage soil, woodfuel, and agroforestry resources. Public policy and development programs can be improved through a better understanding of the household characteristics that significantly influence the decision to adopt soil conservation practices. The factors that drive adoption decisions are explored through a series of behavioral models presented in the next two chapters. Models are estimated under dichotomous choice and intensity of use frameworks in chapter 2. In chapter 3, adoption is analyzed as a choice between different types of practices through a multinomial logit model. A related question of interest is: what are the financial returns for soil and water conservation practices currently used by households? Estimates for a Cobb-Douglas production function are presented in chapter 2 in order to determine the changes in agricultural revenues that can be directly attributed to the use of common soil conservation practices. Woodfuel management is explored in chapter 4. Binomial choice models are estimated for the decision to participate in charcoal production and the decision to plant trees, including those that are used for fruit. Chapter 4 also examines the empirical links between tree planting and the harvesting of woodfuel for charcoal through a series of hypothesis tests. Together, the empirical results presented in chapter 4 provide important insights into woodfuel and tree planting behavior by smallholder households in Central Haiti.

The analyses presented in the next three chapters are contributions to the economics literature related to smallholder adoption, soil conservation, natural resource management, and woodfuel. The results are especially significant contributions to the relatively limited body of work on Haiti. Globally, most previous soil conservation practice adoption studies only examine one type of practice, or combine multiple practices into one category. However, soil conservation practices require different levels of investment and have different functional attributes. A limited number of studies have compared the adoption process of a range of practices using the same data set. Chapter 2 and chapter 3 consider multiple categories of practices common in Haiti and in other countries with different econometric methods. Only one other study has compared the factors affecting investment decisions for different SWC practices in Haiti (Bayard et al. 2007), and the work presented in chapter 3 is the first known application of a multinomial choice model in Haiti.

Few studies have looked at the performance of SWC practices in Haiti. Chapter 2 contains the first known application of an agricultural production function in Haiti and one of the first studies on conservation practice performance in the country. The results from the tree planting adoption model, the charcoal participation model, and other statistical analyses in chapter 4 are also significant contributions to the literature on woodfuel and natural resource management in Haiti. Together, they represent one of the few empirical analyses of smallholder charcoal production and tree planting in Haiti. The analyses presented in the remaining chapters are also noteworthy due to the use of a recent and relatively large household data set.

The basis for the empirical analysis presented throughout this dissertation is a household survey completed for 2011 in Central Haiti. The region where the survey was administered is also commonly referred to as the Central Plateau. The one-year recall survey captured a wide range of data related to demographics, heath, expenditures, natural resource management, migration, markets, and social networks. The data set includes information for households across varied topographic, agronomic, and socioeconomic conditions representative of those on the Central Plateau and the rest of Haiti.

The results of the behavioral models presented in chapters 2 and 3 provide important insights into the drivers of the adoption of soil and water conservation practices. Market access and the availability of credit are both found to be significant factors. Other household and plot characteristics such as perceived soil quality, land tenure, and health status also influence conservation behavior. These factors are also to found influence the adoption decision for different practices in different ways, thereby highlighting the important distinctions made between soil conservation practices. The estimated production function in chapter 2 also revealed positive returns from certain types of conservation practices. Estimates of the production function are valuable in that they can provide the basis for the comparison of the benefits and costs of conservation programs. The behavior models are complemented by the empirical analysis of woodfuel management presented in chapter 4. Evidence is provided that supports the position that tree planting and charcoal production decisions are part of a woodfuel management strategy used by many households in Central Haiti. Together these results from Chapters 2, 3 and 4 inform the design and targeting of new programs related to soil conservation and natural resource management. They have clear implications for policy decisions related to rural Haiti and other developing countries were the smallholders face similar challenges.

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CHAPTER 2

ECONOMIC ANALYSES OF SOIL CONSERVATION PRACTICES IN CENTRAL HAITI

2.1 Introduction

Haiti suffers from extreme poverty. The UNDP ranks the country 168 out of 187 on its 2014 Human Development Index (UNDP 2014). This is the lowest ranking in the Western Hemisphere. Half of the population lives on less than one dollar a day and three-quarters have less than two dollars per day (Verner 2008). Approximately 6.7 million Haitians, or two-thirds of the population, are estimated to be food insecure (World Food Program 2013). Poverty is especially acute in rural areas where agriculture plays an important role in household livelihoods. Approximately 70% of the country's poor live in rural areas.

Poverty and pressures from population growth have resulted in the overexploitation of forest resources for fuel, income, and agricultural expansion. While forests covered nearly the entire country prior to European colonization, today, there is not much left. As recently as 1950 forest cover was reported to be around 20%. Approximately 9% was left in 1978 (Smucker et al. 2007) and in the past 32 years much of the remaining forests have been cleared, reducing current forest cover to 3.4% (FAO 2014).

Today, there is essentially no forest-agriculture margin, and a large portion of the rural population practice agriculture on deforested and highly eroded hillsides not suitable for agricultural production. Approximately 40% of Haiti's hillside farms are on slopes that exceed 50% (Smucker et al. 2007). Farming under these conditions is not sustainable. The World Bank estimated annual rates of erosion equal to 36.6 million tons per year under current land management practices (as cited in Jolly et al. 2007). Agricultural productivity is very low under these conditions. Countrywide, the FAO reports that yields in Haiti of maize, pigeon peas, and beans are 45%, 31%, and 70% of what they are in the Dominican Republic, respectively (FAO 2014).

2.1.1 Soil conservation programs in Central Haiti

Many within and outside of Haiti have tried to curb the alarming rates of soil erosion and broader environmental degradation. There is a sixty-year legacy of large-scale programs aimed specifically at soil conservation which are funded almost entirely by outside donors. In the 1950s, through the 1970s, soil conservation projects were focused on large engineered structures, including rock walls and contour canals. These projects were administered primarily by the Government of Haiti and completed using wage labor. Structures often crossed property lines and did not always solicit landowner participation (Smucker et al. 2007). In the 1980s, there was a notable shift to plot-based approaches. New projects began to focus on agricultural practices such as agroforestry and contour hedgerows. In the 1990s, these projects transitioned towards watershed-level strategies while still promoting plot-level soil conservation practices. According to some estimates, by 1999 about 1.2 million meters of hedgerows had been established throughout Haiti from United States Agency for International Development (USAID) sponsored efforts (Bannister and Nair 2003). Most recently, donor-funded projects have shifted toward improving local and national watershed governance while promoting sustainable agricultural practices through market-based incentives.

Almost all of the efforts mentioned above have failed to achieve significant landscape-level changes. However, the legacy of these programs can still be found throughout Haiti, and specifically on the Central Plateau in Haiti. This legacy can be seen in the adoption and adaptation of the soil conservation practices promoted by different organizations. Smallholder households in the region use a diverse array of practices. Some incorporate live plant material and can provide important sources of food, fuel, and fodder. Other practices are structural features such as rock walls or soil bunds and require different combinations of labor and capital to establish and maintain. At least eight distinct types of soil conservation practices can be found in Central Haiti (see the next section and Table 2.1 for detailed descriptions).

2.1.2 Identification and classification of common conservation practices in Haiti

A common soil and water conservation (SWC) practice found in Haiti is referred to as *barye vivan* in Haitian Creole. *Barye vivan* consist of hedgerows or plants established along the contour. They are normally composed of grasses, woody plants, or perennial food crops. Development practitioners often refer to these structures as live barriers. Studies have shown that Haitian farmers often modify project-promoted live barriers to include perennial crops[1] that can be used for consumption or sale (Murray and Bannister 2004). Soil conservation practices that do not directly utilize live plant material in their construction are referred to as dead barriers. They include *mi sék*, which are rock walls with some degree of terracing, and *kodon pyé*, or rock walls or barriers that are less substantial than a *mi sék*. Other dead barriers found within the study area are *fasinaj*, *biyon*, *kleyonaj*, and *kanal kontou*.

The differentiation of SWC practices into the live and dead barrier categories is meaningful in the analysis presented in this chapter. Estimating separate behavioral models for each SWC practice would not yield good results given the low incidence of some practices. At the other extreme, important

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[1] The food producing plants commonly used with *barye vivan* are distinct from those that make up the value of production dependent variable in the production function presented in section 2.3.3.

insights into household behavior and production may be lost with the aggregation of all types of practices into one SWC practice classification. They have different functional attributes, labor requirements, and capital inputs. Consequently, households perceive them differently. Live barriers are often promoted with farmers in Haiti for their soil fertility enhancing characteristics, thereby supporting a perceived differentiation. Relatively few behavioral or productivity studies have the explicitly stated objective of modeling different kinds of practices concurrently (Burton et al. [1999], Bekele and Drake [2003], and Ersado [2004] are exceptions).

Another important aspect of many SWC practices in Central Haiti is that they have been used for some time and are not currently widely promoted by non-governmental organizations or the Government of Haiti. Therefore, the economic models in this chapter related to SWC practices and their benefits could be evaluated in the context of long-term adoption. More specifically, the behavioral models correspond to continued utilization manifested through the continued maintenance SWC practice as reported by the household. This type of analysis in framed by the cross-sectional dataset described in section 2.4. The use of SWC practice under this context is still commonly referred to as adoption (Feder et al. 1985). Both “adoption” and “utilization” are used interchangeably in the remainder of the chapter.

The lack of active soil conservation programs, the relatively long-term use of SWC practices, and adoption without the influence of outside actors all support the idea that households on the Central Plateau are relatively far along the technology adoption curve. Under the diffusion of innovations theory, those recently adopting SWC practices within the region for the first time would be considered part of the “late majority” or “laggards groups" (Rodgers, 2003). However, these late adopters are found to be only a very small fraction of households currently using SWC practices.

2.1.3 Literature review

A brief review of the economic literature related to smallholder adoption and the estimation of SWC benefits is presented below. A global review is offered in addition to a discussion of all known studies completed in Haiti. The objective is to establish the basis for which the research presented in this chapter makes a significant contribution.

2.1.3.1 Smallholder adoption

There is a large body of literature on the adoption of agricultural technologies. Both theoretical and empirical work on the subject sprang from the analysis of programs promoting high-yielding crop varieties and fertilizers as part of the Green Revolution in India during the middle of the 20th century.

These early studies provided important insights into the drivers of the adoption of agricultural technology. Factors such as farm size, risk, uncertainty, human capital, labor availability, credit constraints, and land tenure were found to affect adoption (e.g., Feder et al. [1985] and Ruttan [1977]). There have since been numerous smallholder adoption studies around the world in the contexts of both developed and developing countries. Work has also expanded to include the examination of adoption of conservation practices and the application of an expanding array of modeling and econometric techniques (Doss 2006).

Most of the early empirical studies utilized aggregate data for a given geographical region rather than the farm- or plot-level. During the 1980s, researchers began to use farm-level cross-sectional data sets that facilitated a deeper examination of smallholder adoption behavior. Jamison et al. (1984) and Rahm et al. (1984) are two early studies that used cross-sectional data to estimate the drivers of the adoption of SWC practices.

The first empirical studies with cross-sectional data examined adoption with a simple dichotomous (adopter/non-adopter) framework. The presence of a technology or management practice on a farm, regardless of the extent of use, is considered sufficient criteria for a farmer to be labeled as an adopter for these types of studies. However, this is not the only definition of adoption. There are also continuous measures of adoption, such as the fraction of land in which a new technology is used. The criteria used to define adoption matters, as studies have shown that different factors can influence the initial decision compared to the intensity of use (e.g., Gebremedhin and Swinton [2003], Genanew and Alemu [2012]). For the adoption models in this chapter (excluding the intensity of use model) any positive and current use of a practice is defined as adoption.

The timing of household observations in relation to technology introduction, the learning process, and socioeconomic dynamics are also important factors in defining adoption. Feder (1985) defines adoption as "… the degree of use of a new technology in long-run equilibrium when the farmer has full information about the new technology and its potential." There are numerous examples within the literature on agricultural technology diffusion that demonstrate that different farms with different characteristics adopt at different times prior to reaching a long-term equilibrium state (Geroski 2000). The SWC practices examined in this chapter were promoted through donor-funded projects during the 1980s and 1990s. This relatively long period since the introduction and promotion of SWC practices supports the idea that smallholders on the Central Plateau are sufficiently far along the technology diffusion curve. Smallholder households have full information on commonly used SWC practices, and it can therefore be safely argued that the adoption studied within this chapter is in agreement with Feder's definition.

With early farm-level empirical work on adoption, researchers began to develop behavioral models that examined the intensity of technology use or adoption. Ervin and Ervin (1982) first analyzed the intensity of use with a two-stage approach, whereby a model of the decision to adopt is followed by a linked model for the level of investment in SWC practices. Norris and Batie (1987) combined these two decisions using a Tobit model for soil conservation practices in Virginia. Tobit and other two-stage integrated econometric methods have since been used extensively to examine the intensity of use of SWC practices (e.g., Gould et al. [2008], Lynne et al. [1988], Feather and Amacher [1994], Genanew and Alemu [2012]).

Most studies related to SWC adoption only examine one type of practice, or combine multiple practices into one category. However, SWC practices require different levels of capital, labor, and expertise. They also have different functional attributes that vary depending on cropping systems and plot characteristics. A limited number have compared the adoption process of a range of practices using the same data set. Gebremedhin and Swinton (2003) and Anley et al. (2007) model and compare the adoption and intensity of use decisions for a variety of SWC practices in Ethiopia. Nkegbe et al. (2012) offers another example from Ghana. The authors find that household and plot characteristics affect adoption decisions for stone bunds, soil bunds, and grass strips in different ways. Only one known study has compared the factors affecting investment decisions for different SWC practices in Haiti (Bayard et al. 2007).

2.1.3.2 Value of conservation practices

Agronomic research has shown that the types of SWC practices found in Central Haiti can significantly mitigate soil erosion and improve yields through improved water retention and soil structure (e.g., Toness et al. [1998]; Zougmoré et al. [2004]; Tenge et al. [2005]; and Chirwa et al. [1994]). Economic studies have also been able to estimate the benefits of SWC practices. Shively (1999) estimated corn yield increases of up to 15% with the use of contour hedgerows on hillsides farms in the Philippines. A similar study in the Philippines by Pattanayak and Mercer (1997) also shows significant gains through soil conservation. Contour hedgerows were estimated to improve average agricultural productivity by 10% ($51/year). Adégbidi et al. (2004) found that plot-level productivity increased by as much as 71% with the use of rock barriers similar to *kodon pyé* in Benin.

Productivity gain estimates from economic studies are generally based on production functions. Under this modeling framework, the amount harvested or the value of the harvest is regressed on a variety of explanatory variables including those that describe SWC practices. The causal effects of SWC practices are identified through their estimated coefficients. Other common explanatory variables include labor, inputs, and plot specific characteristics such as slope and soil fertility. A Cobb-Douglas functional form is widely utilized, as is the case for Shively (1999) and the other examples presented above.

2.1.3.3 Related research in Haiti

The majority of the research on the adoption of SWC practices in Haiti has focused on the role of land tenure, project-based incentives, collective action, and environmental perceptions. This work has largely followed donor funded agroforestry and reforestation projects. Researchers and policymakers alike have sought to better understand the incentives for and the constraints to widespread adoption of sustainable agricultural practices and natural resource management.

Haiti lacks a formal land tenure system that is accessible for the majority of its population, especially the rural poor. As a result, only a minority of agricultural households have legal title to their land. Informal land tenure systems are largely functional[2], but researchers and policymakers have still sought

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[2] The customary tenure system predominant in rural Haiti today, has remained essentially unchanged for many years. See Murray (1977) for a thorough presentation on the history of land tenure in Haiti.

to determine if the lack of legal tenure is a significant constraint on investments in SWC practices and other sustainable practices. Beginning in the 1980s, the common view held by USAID and other actors in Haiti was that legally recognized tenure was necessary for farmers to invest in reforestation, agroforestry, and SWC practices (Smucker et al. 2002). Many researchers have argued that tenure conditions were not significant factors in landholders' willingness to plant trees or invest in soil conservation practices (e.g., Bloch et al. [1988]; Smucker et al. [2002]; Bannister and Nair [2003]). This work has influenced development policy, and natural resource management projects now work within the customary tenure system rather than avoiding it. Still, the debate has continued, and some have published papers stating that tenure regimes are significant factors in the adoption of conservation practices and reforestation in Haiti (see Bayard et al. [2007], Dolisca et al. [2007], and Collier [2009]).

Natural resource management projects have sometimes subsidized smallholder investments such as seedlings and paid labor. For example, a large USAID reforestation program in the 1980s provided seedlings at heavily subsidized prices (Smucker 2003). USAID in Haiti took a new stance on this policy in the 1990s, insisting farmers pay the full price of any investments in soil conservation and tree planting. Practitioners and researchers criticized this policy (see Murray and Bannister [2004] for a related discussion). In the wake of these shifts in policy, researchers have found that smallholders are willing to invest in improved practices without subsidies but only under certain conditions. First, the practices must fit with the smallholder's aversion to risk (Smucker et al. 2002). Second, investments should involve the household's own labor and labor provided through traditional labor exchange groups (Anderson et al. 1995). Lastly, investments must provide tangible profits in the short-term. This last condition is shown through the farmer-led development of *bann manje* conservation practices.

The research related to the environmental perceptions of smallholders in Haiti has arisen primarily out of work in the Pine Forest Reserve. In a series of papers, the perceptions and adoption behavior of over 240 households living in the reserve were assessed (see Dolisca et al. [2006]; Dolisca et al. [2007]; Dolisca et al. [2008]; Dolisca et al. [2009]). The research showed that the farmers viewed the forest as an economic asset, a finding that resonates with research and practitioner experience over the last 40 years. Residents in the reserve also viewed the remaining forest as a source of environmental services such as disaster mitigation, soil conservation, and clean water.

Another related topic of research is collective action in soil conservation and the role that cooperation plays in the adoption of sustainable practices. An empirical study completed in 1995 on the Central Plateau shed some light on how collective action can be mobilized and what factors are significant in farmer participation (White and Runge 1995). The study examined 22 small watersheds that were part of the United States Agency for International Development's (USAID) reforestation efforts in the late

1980s. Prior membership in social organizations, practical knowledge of potential gains from cooperation, and some potential to gain from that action were found to be the primary drivers of participation in watershed management activities. Free riding was not found to be a serious problem.

Bannister and Nair (2003) examined the adoption of tree-based hedgerows that were promoted as part of a series of USAID-funded projects between 1982 and 1991. These projects claimed to have distributed trees to 25% of the rural population. They were active across the country, including the area surveyed for this study. Using nonparametric tests for correlation, the researchers provided evidence that a number of household and plot characteristics were correlated with the planting of fruit trees and top-grafting. The adoption of fruit tree hedgerows was correlated with plots that were more steeply sloped, less fertile, and with less secure tenure. The correlation between hedgerow adoption and other household and plot characteristics was not found to be significant at reportable levels.

A study by Bayard et al. (2007) examined the determinants of alley cropping adoption and degree of management from a sample of two villages in Southern Haiti. Alley cropping can be considered part of the *barye vivan* categories presented above; however, it differs from similar practices in that the hedges that make up the barrier are primarily used to enhance soil fertility through the pruning and application of hedgerow cuttings. Using a probit model, the authors found that adoption was positively affected by group membership, participation in training on conservation practices, and household per capita income. An education and income interaction term (formal education dummy multiplied by household per capita income) and a gender dummy variable (1 if head of household is male) were also significant and found to have a negative effect on alley cropping adoption. Using a multinomial probit model, the authors found that plot size and gender positively affected the degree of hedgerow management. The number of family laborers was found to negatively affect the degree of management. Head of household age increased the probability of higher levels of management up to 51 years old, and had a negative impact thereafter.

Bayard et al. (2006) used a nearly identical methodology in a study on the adoption and management of rock walls in a village on the mountains south of Port-au-Prince. Similar results were found for the adoption model with respect to the positive impact of income and conservation training. However, the signs for gender and group membership were reversed. The results of the multinomial probit management model were largely consistent with the previous results on hedgerows, but the use of different explanatory variables makes a comparison between the two models rather difficult.

Both adoption studies by Bayard et al. for alley cropping and rock walls did not use variables for land tenure, access to markets, diversity of production (a potential proxy for risk preferences), plot specific characteristics, and some household characteristics that may be relevant to behavior modeling (e.g., health status and household size). Notwithstanding the omission of these potentially important variables and different study areas, the two Baynard et al. adoption models provide a comparison to the results presented below in section 2.5. They also show that household characteristics have distinct impacts on the decisions to use live and dead barriers.

Few studies have estimated the benefits of SWC practices in Haiti. One exception is a study by Lutz et al. (1994) conducted on the Central Plateau, the same area examined in this chapter. They reported that plots with conservation barriers produced between 22% and 51% more corn and sorghum. The costs associated with these structures are significant, and they can sometimes inhibit adoption. Both live and dead barriers take some land out of production. There are also varying amounts of labor and capital required for construction and maintenance. Despite these significant costs, Lutz et al. found that both types of barriers had a positive return on investment within one year. They estimated a net present value of $1,180 for live barriers and $956 for rock walls over a fifty-year time frame[3].

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[3] The authors used a discount rate of 20%.

2.1.4 Outline for the remainder of the chapter

The remainder of this chapter is organized as follows. A theoretical model of smallholder household behavior is presented in section 2.2, followed by the econometric specification in section 2.3. The survey methodology and descriptive statistics are presented in section 2.4. Section 2.5 contains the results for probit adoption models that consider the adoption of different categories of SWC practices. A Tobit model is also estimated in order to examine the intensity of use of various SWC practices. Lastly, section 5 contains the results from a Cobb-Douglas production function estimation. The chapter concludes in section 2.6 with a discussion of the implications for the design of policies related to soil conservation in Haiti and similar locations.

2.2 Household utilization of conservation practices

The agricultural household model that serves as the basis for the empirical analysis in this chapter relies on a number of key assumptions common in the literature that allow proper framing of the underlining economic theory. The economics approach is based on a representative household making consumption and production decisions that generate income and food through agricultural production. In the SWC practice adoption problem examined in this chapter, as in other studies of this type, the consumption side in the theoretical model is simplified in order to focus on production decisions where SWC practices are important. Given the assumption of the separability of production and consumption decisions, as discussed below, the results would remain in a more complex model with differentiated labor and consumption.

In many areas of developing countries, rural markets may be affected by high transaction costs or they may be non-existent. However, there are market and household characteristics Central Haiti that justify the assumption of separability.. First, markets for labor, land, agricultural commodities, and agricultural inputs are present and relatively complete. Very often the low population densities and poor infrastructure characteristic of many rural regions in developing countries are the leading causes of market failures. However, Central Haiti has a relatively high population density, new road infrastructure, and many rural markets, even in areas accessible only on foot. These conditions generally allow markets to function without significant constraints or imperfections. Results presented below show that households are indeed contracting and participating in wage labor for agricultural activities. Field observations, interviews, and survey results support the premise that commodity and land markets are complete. A wide range of non-labor inputs is not commonly used, but those that are (e.g., open pollinated seed) are easily accessed across the study area. Credit (formal or informal) must also function well for the separability condition to hold. The survey results that follow also provide evidence of household participation in robust credit markets. Additionally, households must be indifferent between the use of hired labor and their members for agricultural production. Paid and unpaid labor exchange between households is common, which may reflect the lack of strong preferences towards labor categories. Lastly, they must also be indifferent to the consumption of their own agricultural production versus food purchased on the open market. The food that is available in local markets is essentially identical to food grown by smallholder households. The similarity of products suggests that household food preferences may not be strong enough to violate the condition of separability.

While this chapter does not test the validity of the assumption of separability, variables related to household composition and other factors that should not affect agricultural production decisions are still included in the econometric models presented in section. This is done so that the estimated behavioral models remain largely consistent in the event that there are market failures that result in a violation of the separability assumption.

Additional assumptions specific to SWC practices are also made with the theoretical household model. First, the benefits from conservation are only realized through agricultural production of the representative crop. A second assumption is that there are no efficiency gains from the simultaneous adoption of different kinds of SWC practices. While efficiencies may be possible, production function estimates did not show any significant interaction terms for simultaneous use of different SWC practices.

2.2.1 A separable smallholder household model

Consider a representative household i that maximizes its utility, represented by a continuous, twice-differentiable, and quasi-concave utility function:

$$U_i = U(x_h, x_m, l; \alpha), \qquad (2.1)$$

where x_h is consumption of a representative product (i.e., consumption is an index variable) produced by the household, x_m is the consumption of a representative (index) market good, and l is the amount of total household time spent on leisure.[4] The last variable α captures other exogenous factors that influence household utility. The household will maximize utility with respect to x_h, x_m, and l, subject to the following constraints:

$$T = l + L_o + L_h \qquad (2.2)$$

$$L = L_h + L_w \qquad (2.3)$$

$$y = f(L, X, \boldsymbol{D}; \psi) \qquad (2.4)$$

[4] The i subscript suppressed in what follows for notational simplicity,

$$p_m x_m = p_y(y - x_h) - wL_w + wL_o - p_x X - \boldsymbol{p}_{\boldsymbol{D}}' \boldsymbol{D} + z. \tag{2.5}$$

The first constraint is a time constraint that equates the household's time endowment, T, to time spent with leisure, off-farm wage labor by household members L_o, and time dedicated towards household agricultural production L_h. The second constraint simply states the total amount of labor allocated towards production represented by L is equal to the sum of household agricultural labor and hired labor L_w. The next constraint is a production function $f(\cdot)$, which describes production possibilities for the household and that without loss could describe production income if crop prices are used. Under this constraint, production of a representative commodity y is a function of labor time L; the area managed under various SWC practices used as represented by the vector $\boldsymbol{D}$; and an index variable for non-labor inputs X. Other exogenous factors that influence production such as plot slope and soil quality are captured by the variable ψ in (2.4). It is assumed conventionally that SWC practices increase production for a household that uses them, so that $\partial f(\cdot)/\partial D_n \geq 0$ and $\partial^2 f(\cdot)/\partial D_n^2 \leq 0$, for all elements D_n that compose $\boldsymbol{D}$. The last constraint defines the household budget, such that there is equality between the value of total consumption and cash agricultural production plus income from off-farm work and exogenous income z, minus the cost of hired labor and any cost incurred for soil conservation efforts (such as maintenance). The amount of own-agricultural production consumed by household i is x_h, and the marketed surplus is $(y - x_h)$.

An important element of this study is described through interpretation of $\boldsymbol{p}_D$ in (2.5). This is a vector of prices so that $\boldsymbol{p}_D'\boldsymbol{D}$ is the total maintenance and other costs of SWC practices utilized by the household at any point in time. The management of the SWC practices under consideration for this study could be interpreted as continued utilization rather than adoption. This distinction is made for two reasons: first, nearly all of the sampled households with soil conservation practices have used them for at least one year, and while there may be some minor modification or innovation with the application of common practices in any given year, their use has been established in the region for some time. Thus, the unit costs of continued utilization of soil conservation practices rather than the cost of establishment is represented by $\boldsymbol{p}_D$. Although some practices such as rock walls may be well established on a given plot, all SWC practices considered in this study require significant levels of annual maintenance. SWC maintenance was considered with the administration of the survey. Dis-adoption is possible for any given practice and in any given agricultural season.

Farm profits can be represented by a continuous, quasi-concave, and twice differentiable equation:

$$\pi(L, X, \boldsymbol{D}; \psi) = p_y f(L, X, \boldsymbol{D}; \psi) - wL_w - p_x X - \boldsymbol{p}_D'\boldsymbol{D}. \qquad (2.6)$$

As discussed above, under conditions for separability, the household model described with equations (2.1) – (2.5) is recursive in that the household makes production decisions by maximizing $\pi(L, X, \boldsymbol{D}; \psi)$. Then, the maximum profits attained through these production decisions become part of the cash budget constraint that defines household utility maximization choices. The resulting first order conditions of the profit function with respect to labor L, the variable input X, and SWC practices are:

$$p_y \frac{\partial y}{\partial L} = w \tag{2.7}$$

$$p_y \frac{\partial y}{\partial X} = p_x \tag{2.8}$$

$$p_y \frac{\partial y}{\partial D_n} = p_{D_n} \, . \tag{2.9}$$

These conditions show that the household makes production decisions to equate marginal products for labor, inputs, and soil conservation efforts to their respective marginal costs. In other words, utilization of a given conservation practice proceeds up to the point where the cost of an additional investment is greater than its benefit in terms of increased production income. Factor demands, of which SWC practices are a subset, are derived through the first order conditions; thus the demand for D_n is:

$$D_n^* = D_n\left(p_y, w, p_x, \boldsymbol{p}_D\right). \tag{2.10}$$

Optimized levels of L, X, and the optimal SWC regime D_n^* from the factor demands are then used to define a maximized profit value as:

$$\pi^*(L^*, X^*, \boldsymbol{D}^*; \psi) = \pi^*\left(p_y, w, p_x, \boldsymbol{p}_D; \psi\right). \tag{2.11}$$

Through Hotelling's lemma and the definition of the profit function, the demand for the n^{th} SWC practice D_n can also be expressed as:

$$D_n\left(p_y, w, p_x, \boldsymbol{p}_D\right) = -\frac{\partial \pi^*}{\partial p_{D_n}}. \tag{2.12}$$

so that the decision to use the n^{th} SWC practice depends critically on expected changes in profits as well as the cost of the practice.

The indirect utility function can be derived by returning to the household utility maximization problem and defining a cash budget constraint using the maximized profit function in (2.11) to describe 'full income' M of the optimizing household:

$$M \equiv p_m x_m + p_y x_h + wl = \pi^*(p_y, w, p_x, \boldsymbol{p_D}; \psi) + wT + z. \tag{2.13}$$

The first order conditions for the decision variables x_m, x_h, and l are then:

$$\frac{\partial U}{\partial x_m} = \lambda p_m \tag{2.14}$$

$$\frac{\partial U}{\partial x_h} = \lambda p_y \tag{2.15}$$

$$\frac{\partial U}{\partial l} = \lambda w \tag{2.16}$$

$$p_m x_m + p_y x_h + wl = \pi^*(p_y, w, p_x, \boldsymbol{p_D}; \psi) + wT + z. \tag{2.17}$$

The optimal choices solved from the first order conditions are defined notationally as x_m^*, x_h^* and l^*.

Substituting these choices into (2.1) one arrives at a maximized value of utility (i.e., indirect utility):

$$U(x_m^*, x_h^*, l^*; a) = V[\pi^*(p_y, w, p_x, \boldsymbol{p_D}; \psi) + wT + z, w; a]. \tag{2.18}$$

Equation (2.18) demonstrates how SWC management decisions enter the indirect utility function through the profit function as a component of total income.

2.3 Econometric specification

This chapter considers SWC management decisions with dichotomous choice and intensity of use frameworks. In the theoretical model above, households select different levels of use for all elements D_n within the practice vector $\boldsymbol{D}$. A given management regime with intensity decisions for all SWC practices within $\boldsymbol{D}$ can be expressed as a SWC management choice for the household. Under the intensity of use framework considered in this chapter, D_n takes on values greater than or equal to zero, corresponding to the area managed using the practice. A simple representation of the relative expected utility demonstrates a household's choice to utilize the n^{th} practice:

$$U_{in} > U_{i0} \tag{2.19}$$

where U_{in} represents the expected utility with any amount of area managed under the practice n and U_{i0} represents non-adoption. Thus, equation (2.19) describes the case concerning D_n where the utilization of the practice is chosen over non-use; this happens only if the household perceives itself as better off from this choice. If the n^{th} practice is adopted the related decision on intensity of use is made through maximizing profits, resulting in the establishment of a SWC practice up to the point where its value marginal product is equal to its marginal cost. Under a dichotomous choice framework, D_n can be reinterpreted as an indicator variable, whereby D_n would simply take on values of zero or one, for non-adoption or adoption respectively. The econometric form describing utilization in this case is:

$$D_{in} = \begin{cases} 1 \; if \; U_{in} > U_{i0} \\ 0 \; if \; U_{in} \leq U_{i0} \end{cases}. \qquad (2.20)$$

Following the literature on random utility models, the representative utility of household i with a given management decision for SWC practice n is expressed in estimable form as:

$$U_{in} = \mathbf{Z_i}'\boldsymbol{\alpha_n} + \varepsilon_{in}, \qquad (2.21)$$

where $\boldsymbol{Z}_i$ is a vector of observable plot and household characteristics related to agricultural production, with corresponding coefficients $\boldsymbol{\alpha}_n$. The stochastic error term ε_{in}, is a representation of unobservable factors that influence the adoption decision. The term can include factors known to the household that are unobservable in the data, but for which information is collected on other variables correlated with unobservables, such as education as representative of farmer skill.

The econometric form of the production function presented in this chapter stems directly from equation (2.4). The production function is rewritten $y = f(L, X, \boldsymbol{D}; \psi, \varepsilon)$ as a stochastic function of an error term ε, similar to the step taken with the indirect utility function.[5] The error term is again incorporated to account for any potentially unobserved factors that influence production.

[5] The ε variable is used in both the production function and indirect utility function for notational convenience. It accounts for a different set of unobserved factors in each case.

A probit model is used to describe the empirical realization of (2.19) under a dichotomous choice framework and a Tobit model is used for intensity of use. Productivity gains from the use of SWC practices are estimated with a Cobb-Douglas production function. These models are described in more detail below. Together they will offer results that provide a broad view of the household behavior and production related to conservation practices.

2.3.1 The probit model

Under dichotomous choice the probability that $D_{in} = 1$ can be expressed as:

$$P_{in} = \text{Prob}(D_{in} = 1) = \text{Prob}(U_{in} > U_{i0}) \tag{2.22}$$

$$= \text{Prob}[\boldsymbol{Z_i}'\boldsymbol{\alpha_n} + \varepsilon_{in} > \boldsymbol{Z_i}'\boldsymbol{\alpha_0} + \varepsilon_{i0}] \tag{2.23}$$

$$= \text{Prob}[\varepsilon_{in} - \varepsilon_{i0} > \boldsymbol{Z_i}'(\boldsymbol{\alpha}_n - \boldsymbol{\alpha}_0)] \tag{2.24}$$

$$= \text{Prob}(\mu_{in} > \boldsymbol{Z_i}'\boldsymbol{\beta}_n) = F(\boldsymbol{\Upsilon_i}'\boldsymbol{\beta}_n), \tag{2.25}$$

where $\mu_{in} = \varepsilon_{in} - \varepsilon_{i0}$ is a random disturbance term, and $\boldsymbol{\beta}_n = \boldsymbol{\alpha}_n - \boldsymbol{\alpha}_0$ is a vector of coefficients. It is assumed that the disturbance term ε_i with μ_i is normally distributed with a mean equal to zero. A probit model is used in this study, and therefore $F(\boldsymbol{Z_i}'\boldsymbol{\beta}_n)$ is a cumulative normal function equal to

$\Phi(\mathbf{Z}'\boldsymbol{\beta}_n)$. The marginal effect of Z_{ik} (the k^{th} element of $\boldsymbol{Z}_i$) on the probability of adoption for a given practice is:

$$\frac{\partial P_{in}}{\partial \mathrm{Z}_{ik}} = f(\boldsymbol{Z_i}'\boldsymbol{\beta}_n) \times \beta_{nk} \tag{2.26}$$

where β_{nk} is a coefficient for Z_{ik} within $\boldsymbol{\beta}_n$.

The estimated adoption models presented in section 2.5.2 examine adoption of SWC practices at the plot-level. That is to say that the plot characteristics contained in $\boldsymbol{Z}$ relate only to a specific plot, and the observed adoption decision also only applies to the same plot. The plot-level variables (Table 2.2) used in the probit models include those that measure the distance to a plot, the use of irrigation, plot slope, soil quality, land tenure, and the diversity of agricultural production. The distance to a plot variable is included to account for potential preference towards greater investments in agricultural assets that are located closer to the household. As discussed in section 2.1.3.3, the role of land tenure in agricultural and natural resource investment decisions in Haiti has been debated over many years. The role of the tenure variable in the probit models is not expected to be significant due to the established customary tenure system found in the region. A diversity of production index variable is included in the model to capture household risk preferences. Risk averse households would be more likely to favor a more diversified production system.

The household variables included in the probit model include those related to assets, household composition, health, and access to markets. Variables for the value of livestock holding, non-farm income, and income from charcoal production are included to account for the influence of household wealth. The average household member sick days (absent from work and other normal activities) and variables for household composition are included to allow for the potential influence of factors that might be significant drivers of adoption in the event that household consumption and production decisions are non-separable.

2.3.2 Intensity of use, Tobit model

Under an intensity of use framework, the decision to adopt a given practice and the decision on the amount of land managed with the practice can be modeled either as decisions that are made separately or jointly. A Tobit model is generally used to examine intensity of use when these two decisions are made jointly. It would be more appropriate to consider these decisions as separate if, for example, a household sequentially decides first on whether or not to use any soil conservation practices followed by a decision on the degree of utilization. The adoption and the intensity decisions could also potentially be determined by different factors. In these situations a two-tier or double hurdle model such as the one proposed by Cragg (1971) is appropriate, whereby a discrete choice model is estimated followed by a truncated regression model using only households with positive levels of SWC practice use. Alternative double hurdle and Tobit specifications using the data presented in this chapter were compared using likelihood ratio tests. The results of the tests support the use of a Tobit model over a double hurdle specification.

The D_{in} dependent variable in the Tobit model represents the area managed under practice n by household i. Intensity of use is modeled at the farm-level, and coverage is assumed for an entire plot if a respondent states that a practice was present on the plot. D_{in} can not take on values less than 0, and is therefore a censored dependent variable. A latent variable D_{in}^* is used where:

$$D_{in}^* = \boldsymbol{Z_i}'\boldsymbol{\beta}_n + \varepsilon_{in}; \tag{2.27}$$

$$D_{in} = 0 \; if \; D_{in}^* \leq 0; \tag{2.28}$$

$$D_{in} = D_{in}^* \; if \; D_{in}^* > 0. \tag{2.29}$$

Note that the coefficients that compose vector $\boldsymbol{\beta}_n$ in equation (2.28) are distinct from those in the probit model.

The expected intensity of adoption is:

$$E(D_{in}|\boldsymbol{Z_i}) = \boldsymbol{Z_i}'\boldsymbol{\beta}_n F(a_{in}) + \sigma_n f(a_{in}), \tag{2.30}$$

where $F(a_{in})$ is the cumulative normal distribution function at $\alpha_{in} = \frac{\mathbf{z_i}'\boldsymbol{\beta_n}}{\sigma_n}$, σ_n is the standard error estimate, and $f(z_{in})$ is the standard normal density function. Consider an explanatory variable Z_{ik} that is an element of $\mathbf{Z}_i$, and its corresponding coefficient β_k, an element of $\boldsymbol{\beta}_n$. The marginal effect of a change in X_{ik} on the expected value of D_{in} is:

$$\frac{\partial E(D_{in}|\mathbf{Z}_i)}{\partial Z_{ik}} = \beta_k\, F(a_{in}). \qquad (2.31)$$

The household explanatory variables used in the Tobit models are assumed to be the same as those used in the probit models. For the plot related variables, some of those used in the probit models are transformed into fractions, with values from zero to one that measure the extent of an agricultural practice or a quality indicator across the total cultivated area of a given household. The transformed plot related variables used with the Tobit models include the fraction of cultivated land area labeled flat, land labeled as poor, and land with legal title. The two other plots related variables used in the Tobit models are the average distance to plot and the diversity of production across the farm. As with the probit models, these types of socioeconomic and agricultural variables have been shown to be significant drivers of household behavior in a wide range of technology adoption studies, including those that consider SWC practices. Similar to the probit models, the Tobit models are estimated using maximum likelihood estimation.

2.3.3 The production function

A Cobb-Douglas specification is used to estimate the production function $f(\boldsymbol{L}, \boldsymbol{X}, \boldsymbol{D}; \boldsymbol{\psi})$, as contained in equation (2.4).[6] The quantity harvested from a single crop is the dependent variable for many Cobb-Douglas production functions. For highly intercropped production systems, such as those that are the norm in Central Haiti, either the quantity harvested from a primary crop group (e.g., grains) or the total value of the harvest is used as the dependent variable. The total value of household crop production represented by variable R is used in this study. Other studies that have used the total value of the harvest for mixed systems include Pattanayak and Mercer (1998), Adegbidi et al. (2004), and Thao (2001).

Farm gate prices are captured in the survey indirectly through the stated value of the individual crop harvests and the total quantity harvested for a given crop. Calculated farm gate prices were found to be relatively constant across the survey area; however, a significant number of unreasonable outlier prices were found with some households. For a given household, stated harvest value is used for crops that fall within plus or minus 50% of the average crop mean unit price. Average price is used for household crop

[6] The variables for labor, inputs, and household and plot characteristics are expanded from single variables as presented in the simple household.

harvests that fall outside of that range. Average price was used for approximately 40% of individual crop harvests.

The Cobb-Douglas setup for estimation is:

$$\ln R_i = \beta_0 + \ln \boldsymbol{L}_i{}' \boldsymbol{\beta}_L + \ln \boldsymbol{X}_i{}' \boldsymbol{\beta}_X + \boldsymbol{D}_i{}' \boldsymbol{\beta}_D + \boldsymbol{\psi}_i{}' \boldsymbol{\beta}_\psi + e_i. \qquad (2.32)$$

The logged labor variables used in the model include the number of household men per karo[7] (greater than 12 years old); the number of household women per karo (greater than 12 years old); the number of man-days of hired labor; and the number of man-days of communal labor on the farm.[8] Additional logged inputs are the area under cultivation (karo) and the fraction of cultivated land under irrigation (measured 0 to 1). Three types of SWC practices are used in the production function: the fraction (again, measured 0 to 1) of cultivated land managed with live barriers, *mi sék*, and *kodon pyé*. The ψ variable used in the Cobb-Douglas equation is different from the one presented in the theoretical model in that it now includes household characteristics.

[7] Karo is local unit of land area measure equal to 1.29 hectares.

[8] For observations with a value of zero, .001 was added to the observation in order to accommodate the log transformations.

The household characteristics and plot characteristics included in the model are the distance to market (minutes traveled on foot); average distance to plots (minutes traveled on foot); HoH age; the number of children (greater than 12 years old); the fraction of land with legal title; a farm crop diversity index; the fraction of land identified as having poor quality soil; and the fraction of land identified as flat. Similar to the behavioral models, some household characteristics are included in the production function in order to allow for factors that may influence production if the assumption of separability between consumption and production decisions does not hold (Benjamin 1992; Pattanayak and Mercer 1998). The distance to market is included to account for the potential travel costs and alternative livelihood opportunities that may influence farmer effort and investment not captured by other variables. Tenure status is included in the production model to capture potential land quality or value placed on the plot by the household that is not reflected in other explanatory variables.

The production function was estimated using ordinary least squares. Special consideration was given to heteroskedasticity, self-selection bias, and potential endogeneity. The Breusch–Pagan test statistic led us to reject the null hypothesis of homoscedasticity. This potential issue was addressed through the use of White's heteroscedasticity-consistent estimator. As in many adoption studies, self-selection bias could lead to misleading results. Estimated inverse-Mill's ratios were used in an otherwise identical production function to detect and correct potential selection bias. The corresponding coefficient was not statistically significant, thereby supporting the specification presented in equation (2.32). Endogeneity is also a common concern with the estimation of production functions, especially with input variables such as labor. This production function uses labor availability and other explanatory variables commonly included in other similar published studies.

2.4 Data and descriptive statistics

The data used in this study were collected as part of the SANREM baseline survey of households completed between 2011 and 2012 on the Central Plateau of Haiti. The purpose of the survey was to serve the agronomic objectives of the SANREM Haiti project by providing basic information on agricultural production and the rural economy. A wide range of data related to demographics, heath, expenditures, natural resource management, migration, markets, and social networks were collected in addition to the data used in the analyses in section 2.5. Descriptive statistics are presented below in addition to the methodology used to design and administer the survey.

2.4.1 Survey methodology

The survey instrument used from July to November 2011 was a one-year recall survey, similar to instruments used in Ersado (2004) and Amacher et al. (2014). It is also based on some elements contained in the World Bank Living Standards Measurement Study (LSMS) survey. A draft survey was first developed in collaboration with Haitian agronomists from local non-governmental organization Zanmi Lansante, agronomists from Virginia Tech, and an economist from the Faculté d'Agronomie et de Médecine Vétérinaire within the Université d'État d'Haiti (UEH). Considerable attention was given to question wording and Creole translation. A pretest was completed during May and June 2011. The results of the pretest led to further revision of the survey instrument and provided insight that aided in the development of the sampling strategy.

The sampling strategy was developed with the objective of collecting data for at least 500 smallholder households that are representative of those on the Central Plateau. At the same time, logistical considerations including accessibility and partner support also influenced the decision on how and where to sample. After consultation with Zanmi Lansante and other experts familiar with the region, a sixteen-by-sixteen kilometer square centered near the town of Duffalty was identified as the sample area.

The sampling area contains varied topography, agronomic conditions, and socioeconomic characteristics that are largely representative of those on the Central Plateau. It includes the mountain regions of Bois Joli and Balandre; the foothills of Boucane Carre and Porc Cabrit; and the lowland areas of Corporant and Grand Savane. Households and their plots varied in elevation from approximately 125 to 825 meters above sea level. Annual rainfall is around 150 cm and follows a bimodal pattern common through most of the country. The rainy season usually begins in late April and ends in November, with the highest amounts of rain during the months of May and August.

Zanmi Agrikol had a broad network of farmers within this area, but they did not have lists of households from which to sample. However, high-quality imagery of the Central Plateau is available through Google Earth. Individual households, roads, waterways, and markets can be identified with considerable accuracy. An area frame approach was adopted based on this available imagery.

The sixteen-kilometer square was divided into 256 one-kilometer square quadrats, which were subsequently used to produce a random sample of 73 one-kilometer square quadrats. Some of the quadrats within the random sample contained more heavily populated areas with more than 100 households, while others were completely unpopulated. A team of six Haitian agronomists, trained in survey enumeration, visited nearly every household within 73 sampled quadrats.[9] Once a household

[9] A total of fifteen quadrats were not visited due to logistical constraints. The omission of these sampled quadrats should not severely bias results due to the fact that many were not populated and all others were sparsely populated.

was identified, an enumerator would flip a coin resulting in a 50% chance that a household within the sampled quadrat would be surveyed. This additional element of randomization was incorporated into the sampling strategy in order to achieve broad coverage of the study area while attaining the target of at least 500 completed household surveys.

In total, over 1,500 households were visited and 600 households were surveyed. Information on 3,282 household members, 1,194 fuelwood collection sites, 1,367 agricultural plots, and 3,278 plantings were collected using the survey instrument. The refusal rate was under 2%.

For most farmers on the Central Plateau the agricultural season begins in April with the beginning of the rainy season. Important crops such as corn and beans are planted during this time and harvested through the late summer. Sorghum and pigeon peas are also planted with the beginning of the rainy season but they are not harvested until February and March of the following year. The household survey completed between July and November 2011 was unable to capture harvest information for all crops, particularity sorghum and pigeon peas. Households with incomplete harvest data were revisited in May 2012. These households were re-administered the agricultural modules from the 2011 survey in order complete the data set.

2.4.2 Descriptive statistics

Information for a total of 1,367 agricultural plots managed by 600 households was collected; however, data were missing for some surveys. A reduced data set of 704 plots belonging to 391 households was used for the probit model. Three hundred and seventy-one households were used for the Tobit models. The production function was estimated using a reduced set of 384 households. All of the reduced data sets were obtained through the removal of all surveys with missing data for any of the variables used in model estimation. No clear patterns could be found within the remaining data between incomplete and complete surveys. Note that conditions that may seriously disrupt a long-term equilibrium state, such as cholera and migration from the 2010 earthquake in Port-au-Prince, were not found to influence SWC practice use.

The average plot was approximately 0.5 karo, located 28 minutes travel time by foot from the household, and had been cultivated for 14 years (Table 2.2). The average household agricultural landholding was 1.1 karo over 1.9 plots (Table 2.3). The largest river in the country transects the survey area, and irrigation was found on 8% of all plots. Households were asked to classify the quality of their soil and plot slope. Twelve percent of plots were classified as having poor soil, and 53% of plots were classified as flat.[10] Fertilizer is applied at very low rates in Haiti, and it is not commonly sold in rural markets. An average of 5 kilograms of fertilizer was applied to fields in 2011, but it should be noted that this relatively large amount was due to a large donation distributed to farmers in the region at the beginning of the year. Approximately 20% of all plots were rented or managed under a sharecropping arrangement. Households held legal title to only 18% of plots, with the remaining 62% managed under customary tenure.

The primary cropping system used within the survey area is highly varied and utilizes a mix of corn, sorghum, pigeon pea, cassava, banana, beans, and peanuts. A Gini-Simpson Index is used to capture the diversity of production within this intercropped system:

$$1 - \sum_{i=1}^{R} p_i^2 , \qquad (2.34)$$

where p_i is the fraction of the market value of the harvest for crop i compared to the total harvest value. The index can take on values from zero to less than one. A value of zero would represent monocrop production, and values closer to one would correspond to a more diversified production. The average Gini-Simpson Index value was 0.45 at the plot-level and 0.56 at the household level.

[10] Households choose from three categories for soil quality (poor, average, and good) and slope (flat, sloped, and highly sloped). These results were transformed into the binary variables described above for modeling convenience.

Households were on average composed of 5.5 members, with 1.7 children below the age of 12 (Table 2.3). The average head of household age was 44.3 years old, with an average of 3.1 years of education.[11] Individuals older than 12 years old were considered part of the household agricultural labor pool. The average amount of household labor available was 3.1 males per karo and 3.1 females per karo. Straight-line distance to the nearest market was estimated using geospatial methods. Households were on average 2.73 kilometers away from the nearest major market where food and other household essentials could be bought and sold. It should also be noted that the location of the nearest market also corresponded with the location of the nearest health center. Household members missed an average of 0.8 days due to illness during 2011.

Average household agricultural production for 2011 was valued at $353. Income from other activities (excluding charcoal) was comparable at $396. There was however significant variation in both sources of income between households, with standard deviations of $489 and $502, respectively. Charcoal production is a common income generating activity on the Central Plateau, and households earned on

[11] Years of education were calculated from categorical responses from the head of household (e.g., the equivalent of completed primary school or some high school).

average $61 from charcoal in 2011. Credit was readily available despite the fact that formal credit and banking services are poorly developed in the region. Households incurred an average of $57 of loans in 2011, suggesting a healthy informal credit market. As in other developing countries, livestock is a significant repository of wealth. Average livestock holdings (including fowl) were valued at $579. Fruit trees are also considered a family asset and an important source of income. Households reported that they owned an average of 19 mature fruit trees.

2.5 Results

Both sets of estimated behavioral models have results that provide valuable insight into soil conservation in Central Haiti. The probit models (Table 2.4) correctly predicted 69.7% of live barrier adoption, 81.8% of *mi sék* adoption, and 81.5% of *kodon pyé* adoption. The chi-square statistics for the live, *mi sék*, and *kodon pyé* models were 130.0, 68.6, and 146.7 respectively with 24 degrees of freedom. The estimated Tobit models (Table 2.5) contain a number of statistically significant coefficients across the three SWC practices.

The estimated Cobb-Douglas production function contained a number of statistically significant coefficients (Table 2.6). Coefficients for variables such as irrigation, farmland, and labor were significant and had expected signs, supporting the validity of the estimated model. Coefficients for two of the three SWC practices were statistically significant. These results provide valuable estimates of the increases in agricultural production from SWC practices in Central Haiti.

2.5.1 Probit estimates

A number of plot and household characteristics can be seen to influence adoption decisions from the estimated probit models. Plot tenure, slope, crop diversity, soil quality, and distance from the household to the plot are all significant independent variables (Table 2.3). At the household-level, adult household members per karo, the number of children, HoH age, HoH education, health status, distance to market, non-agricultural income, and credit all influence adoption. Many of these results are consistent with findings from similar studies (Genremedhin et al. 2003; Nkegbe et al. 2012; Baynard et al. 2007). Differences are also found between the drivers of the probit models for different SWC practices.

Of the three probit models (live barriers, *mi sék*, and *kodon pyé)*, only the adoption of *kodon pyé* was influenced by a plot's distance from the household. The effect was positive, with the probability of adoption increasing by 0.72% for every 10 minutes travel time by foot. *Kodon pyé* could be considered a lower quality SWC practice. It is less substantial than *mi sék*, and live barriers can require more maintenance and can have valuable secondary benefits. Both live barriers and *mi sék* are also likely to perform better. The relatively low potential net returns from *kodon pyé* could explain the positive effect of distance from the household on adoption.

Possession of title for a given plot was found to be a significant factor in the adoption of both types of dead barriers, but not live barriers. The effect was positive for *mi sék* and negative for *kodon pyé*. Formal tenure increased the probability of adoption by 11.3% for *mi sék* and lowered the probability of adoption for *kodon pyé* by 7.6%. These results can again be explained by the different characteristics of the two practices. A large amount of resources must be invested to establish the rock walls and terracing that normally make up a *mi sék*. They are relatively long-term structures, and the possession of formal tenure for the land on which they are built can make the investment more secure. The result for live barriers can be explained by the fact that it can be a relatively short-term investment. The structures can be harvested for food, fuel, fodder, or pole wood over a shorter timeframe, making land security less of an issue. The required maintenance can also be scaled back depending on landowner preferences. Other studies have also shown that land tenure can influence the adoption of comparable SWC practices in similar ways (e.g., Genremedhin et al. [2003]).

As expected, the dummy variable for plot slope (FLAT) was highly significant and had the same expected effect for all three barriers. Plots perceived as flat were between 17.6%, 10.2%, and 11.8% less likely to have SWC practices for live barriers, *mi sék*, and *kodon pyé,* respectively. The result for perceived plot fertility provides additional evidence that farmers view the fertility enhancing functions of live and dead barrier practices differently. Plots perceived to have poor soil are 9.2% more likely to have live barriers. Non-governmental organizations who have worked in the region have promoted the use of live barriers as a fertility enhancing practice, and household behavior seems to be consistent with this relationship.

Risk preferences have been found to affect SWC investments in other studies (Feder and Umali 1993). The plot-level Gini-Simpson Index (PLTDIVER) discussed in section 2.4 could be considered a proxy for risk preferences. The closer the index value is to one, the more diversified farm production is and the more risk averse the farmer. PLTDIVER was positive and significant for the adoption of both live barriers and *mi sék*. This result suggests that risk averse farmers are more likely to adopt SWC practices. They appear to value the erosion mitigation functions of SWC practices along with their ability to regulate moisture content. The latter can reduce vulnerability to weather related risks.

The coefficient for the age of the head of household is significant and negative for *mi sék*, while it is not seen to significantly influence the adoption of live barriers or *kodon pyé*. This result could be expected considering that the establishment of *mi sék* is labor intensive. Younger farmers can lift the large amount of rock necessary to build this type of barrier. Similarly, HoH education was only seen to negatively affect the adoption of *mi sék*. The reasons for this result are less obvious, but perhaps households with less education are less aware of the benefits and costs of the other alternatives. Another explanation could be that *mi sék* requires less skill to establish relative to other practices and that there is a direct link between education and the ability to build these kinds of conservation structures.

Labor and health were both significant factors in the adoption of SWC practices. Female labor availability (FMALEKRO) was significant and negative for live barriers. This result is somewhat surprising, but it perhaps could be explained by the fact that women are the primary participants in petty commerce. There could be greater incentives for families with higher proportions of women to allocate labor towards petty commerce rather than SWC activities. The number of children had a positive effect on the adoption of *kodon pyé*. This suggests that household child labor may be used to establish and maintain these lower quality barriers. Similarly, the number of adult males per karo (MALEKARO) was negative and significant for *kodon pyé*. There may be more valuable uses of an adult male's time than establishing *kodon pyé*.

The average number of sick days per month, represented by HHSICK, had a negative impact on the use of live barriers. The probability of adoption decreased by 6.7% for every additional day sick per month. A household with sick family members may not be able to allocate the necessary time for upkeep, due to the maintenance requirements of live barriers.

The coefficient for distance to market was positive and highly significant for all three practices. For every additional one-kilometer a household was located from the nearest market, the probability of adoption increased by 1.6%, 1.3%, and 2.2% for live barriers, *mi sék*, and *kodon pyé* respectively. This is a logical result if one considers that there are higher travel costs for distant households to participate in food and other markets. This can create the need to be more self-sufficient, relying on one's own production for a larger share of food needs. Greater care and investment in one's plot makes sense in this situation. Additionally, while agricultural labor markets are fairly complete throughout the region, there is a smaller range of jobs further away from population centers and markets. There may be additional household labor available to allocate towards SWC practices.

Both income from charcoal sales and the amount of loans taken in 2011 were found to positively influence the adoption of live barriers and *kodon pyé*. These types of practices can require more maintenance. The additional money available to some households could play a role in the decision to adopt live barriers and *kodon pyé* because of their ongoing requirements. Other non-agricultural income was not influential, and the adoption of *mi sék* was not affected by any source of income included in the model.

2.5.2 Tobit estimates

The three Tobit models used in this study examine the intensity of adoption across the household with the fraction of land with a given SWC practice as the dependent variable. They are based on 371 household observations, and the results are largely consistent with the probit models. Twelve significant variables (with the same sign) are shared in common between the three probit and Tobit models, while only one variable (number of children) for live barriers gains significance (Table 2.5). However, some of the coefficients that were found to be significant in the probit models are no longer drivers of household behavior in the Tobit specification. Across the three SWC practices, a total of seven explanatory variables that influenced adoption did not influence intensity of use.

The fraction of land considered flat was again found to affect the intensity of use decisions for all three practices. Additionally, the coefficients for the fraction of land with formal land tenure were highly significant for both types of dead barriers. Similar to the probit models, the effect of a greater fraction of land with legal tenure was found to positively influence the fraction of land with *mi sék*. The impact was negative for *kodon pyé*.

The estimated model predicts that an additional 0.05 karo would be managed with *mi sék* and 0.08 fewer karo would be managed with *kodon pyé* if a household changes to land with legal title to none. This reinforces the idea that formal tenure is important for large investments such as *mi sék*, while land without formal tenure is a better fit for less substantial structures such as *kodon pyé*. The variables for distance to plots, perceived plot fertility, and crop diversity were significant factors with the probit models, but were not found to influence intensity of use decisions.

The labor related variables MALEKARO, FMALEKRO were significant with the same sign for same practices as the estimated probit models. Similarly, the variable for the number of household member sick days had results similar to the probit estimates. The variable had a negative effect on the adoption of live barriers.

Unlike the probit estimates for live barriers, the coefficient for the number of children within the household was significant and negative. Education costs are often the greatest single expense that a household faces in a given year. The estimated impact of additional children suggests that the burden of school related expenses might inhibit the intensity of use of some conservation practices. As with simple adoption, distance to market was positive and significant for all conservation practices. These results support the idea that households further from markets must be more self-sufficient and are willing to invest more in conservation. None of the income categories used in the models were significant, with the exception of credit for *kodon pyé*. The effect of additional loans taken in 2011 was positive on extent of *kodon pyé* across the farm.

2.5.3 Production function estimates

The production function was estimated using a different set of household-level explanatory variables and was based on a total of 384 observations. As expected, the coefficients for the total land under cultivation and the fraction of land managed with irrigation were both significant and positive. Of the other explanatory variables that were treated as essential inputs and therefore log transformed in the model, only the coefficients for the number of females per karo and the man-hours of hired labor were significant. A greater number of household females per karo had a negative effect on production. This is a result consistent with the impact of the same variable on the behavioral models. There could be alternative activities for women that detract from the generation of agricultural income as they did with

SWC adoption. The number of man-hours of hired labor had the expected positive effect on production. According to the model, a 1% increase in hired labor would result in a 0.048% increase in production.

The estimated model also showed that greater crop diversification had a positive and significant effect on the value of production. This effect could be a result unique to the conditions during the 2011 agricultural season. The number of years of formal education completed by the head of household had a positive and significant effect on production.

Explanatory variables for the fraction of land managed with live barriers, *mi sék*, and *kodon pyé* were included in the production function. The presence of *mi sék* was not found to significantly affect production. This result is somewhat surprising, but it could be explained by the variation in the current state of these long-term structures. The coefficients for both live barriers and *kodon pyé* were positive and significant. The estimated model shows that a household that moves to managing all of its land with live barriers from none can expect a 32.9% increase in production. For *kodon pyé* the effect was even greater. A household without *kodon pyé* could expect an increase of 58.3% if all of its land was managed with the practice. Using the average household agricultural income of $353.67, the annual returns for these SWC practices are $116.36 and $206.19. These results are notable given the extreme poverty pervasive throughout the region.

2.6 Conclusions and policy implications

This study differentiates conservation agricultural practices by their unique functional characteristics and input requirements. In addition to mitigation erosion, live barriers can provide food, fodder, and fuel for households. They also can enhance soil fertility through biotic processes in ways that dead barriers such as *mi sék* and *kodon pyé* can not. Furthermore, live and dead barriers also require different types and levels of capital and labor for establishment and maintenance. The results of the behavioral models provide evidence that these distinctions between live and dead barriers influence management decisions. The unique functional characteristics of SWC practices and how smallholder households perceive them has not been given enough consideration in the design and implementation of development projects. The results from this chapter call to policy makers and development practitioner to ensure that proper weight is given towards household preferences and towards the consideration of the range of characteristics that define conservation practices.

Differences between SWC practices across the two behavioral model categories are most evident through the influence of soil quality, land tenure, health, and female labor availability. While perceived soil quality was not a factor in the Tobit model, it was found to have a significant impact in the probit model. There appears to be a perceived fertility enhancing function associated with live barriers that influence adoption. *Kodon pyé* and *mi sék* could be viewed as long-term investments relative to live barriers. Formal tenure was a driver of adoption and intensity of use for dead barriers, but not significant for live barriers. Land tenure appears to influence long-term adoption of some investments in Central Haiti. Many households in the region struggle with disease and illness. Both the probit and Tobit models show that health status is an important driver in the adoption of live barriers, which can require more maintenance. The same maintenance requirements of live barriers could also deter adoption for households with a greater number of women per unit of land. Given the dominant role that women play in petty commerce, there is a greater opportunity cost associated with SWC maintenance for households with greater availability of female labor.

Market access and credit influence the use of SWC practices across almost all of the behavioral models. Households that are further from markets may have to rely more on their own production. The positive effect of distance to market on adoption of all types of practices provides evidence that households that need to be more self-sufficient are willing to invest more to protect vital resources. The positive effect of credit on all practices highlights the importance of finance on offsetting the costs of conservation investments in poor areas like Haiti.

These results have clear implications for project targeting and natural resource management policy. Projects that advocate the use SWC practices must consider the unique characteristics of the households and the practices that they promote. Higher long-term adoption rates of live barriers can be achieved by targeting households that are healthier, are located further from markets, have access to credit, and that have plots that are perceived as having lower fertility. When projects promote dead barriers they must consider additional factors such as land tenure. Policies that influence public health affect farm-level conservation investments. Improved access to commodity, labor, and credit markets also affect SWC investment decisions. No other study of SWC practice adoption has offered this depth of analysis into the drivers conservation behavior. Studies by Bayard et al. (2006 and 2007) used similar methodologies to those presented in this chapter, but their explanatory variables provide little basis for comparison. The findings of the probit and Tobit models offer rare and unique insight into conservation behavior.

However, the smallholder behavioral models a limited in a couple important areas. First, plot characteristics and agricultural performance are based on survey answers rather than field measurements. Second, the cross-sectional nature of the dataset prohibits a more thorough analysis of SWC decisions over time. These are areas for additional potential research. Field measurements would allow for a much more accurate descriptions of SWC practices currently in place. A panel data set would allow for a better understanding of how SWC management changes over time. This aspect is captured to some degree, given the substantial period between when the SWC practices in this study were established and the survey. It is still an incomplete view, and a longer timeframe of analysis could better relate a range of policy decisions (e.g., heath, infrastructure, and financial services) to potential changes in conservation behavior.

The results of the production function also provide valuable insights into the value of SWC practices in the region. Estimated returns from live barriers and *kodon pyé* can be used by policy makers to determine the cost effectiveness of new programs. They also provide evidence as to why these practices have been used by farmers across the region over a long period. There are real economic benefits to households who use conservation practices. The production increase estimates of 32.9% for live barriers and 58.3% for *kodon pyé* are close to estimates by Lutz et al. (1994). This study estimated increases of 22% and 51% for corn and sorghum, respectively, on plots with SWC practices.

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Table 2.1: Common SWC practices in Haiti

Practice*	Classification	Incidence	Description
Barye Vivan	Live	42%	Living barrier or hedgerow
Kodon Pyé	Dead	23%	Rock barrier less substantial than a *mi sék*
Mi Sék	Dead	19%	Rock wall usually with dry wall bench
Fasinaj	Dead	7%	Trash barrier built along the contour
Biyon	Dead	5%	Soil bund or small terrace
Kleyonaj	Dead	2%	Ravine barrier that uses wattle construction
Kanal Kontou	Dead	2%	Contour canal

* The soil conservation practice categories used in this study and this table is taken from (Smucker 2003).

Figure 2.1: Survey area frame with sampled quadrats and households

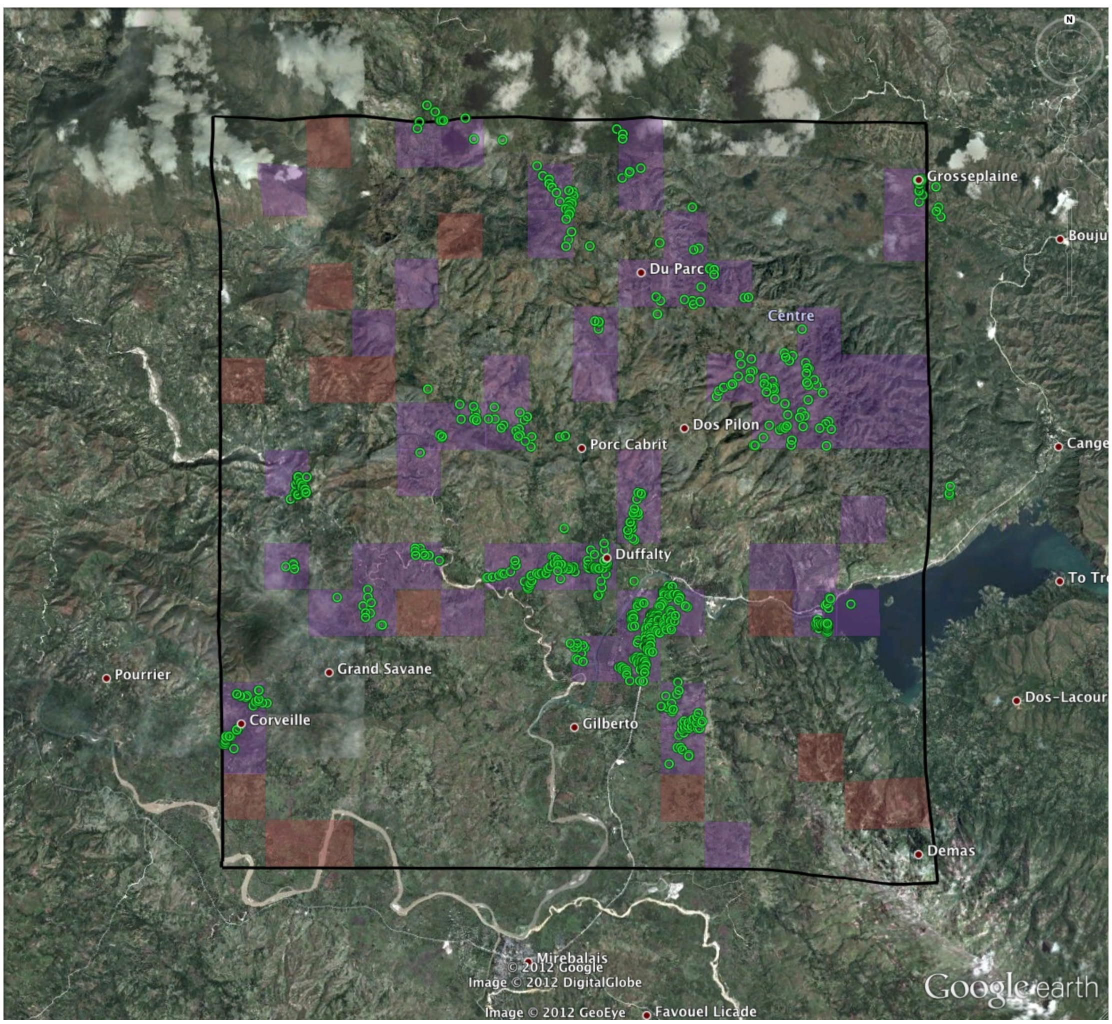

Table 2.2: Descriptive statistics for plot model variables

Variable	Description	Mean	St. Dev.
-	Live barrier dummy variable	0.240	0.427
-	Mi sék dummy variable	0.114	0.318
-	Kodon pyé dummy variable	0.139	0.346
PLTDIST	Distance to plot	27.828	37.705
LANDSIZE	Total household land	1.274	.930
PLOTSIZE	Area of plot	0.509	0.397
PSOILPR	Plot soil quality dummy var.; 1= poor soil	0.105	0.307
PLTTITLE	Tenure dummy var.; 1= plot has title	0.180	0.385
PLTFLAT	Plot slope dummy var.; 1=flat	0.516	0.500
PLOTIRR	Plot irrigation dummy var.; 1=irrigated	0.080	0.271
PLTDIVER	Plot crop Gini-Simpson index	0.446	0.257
MALEKARO	Males (>12) per karo	2.693	3.034
FMALEKRO	Females (>12) per karo	2.598	3.135
CHILDREN	Number of children (12 or younger)	1.517	1.391
HOHAGE	Age of head of household	47.082	13.380
HOHEDU	Years of household head education	2.957	3.442
HHSICK	Average number of household days sick/month	0.783	1.647
DISTMARK	Distance to nearest market	2982.636	2415.139
ANIMALS	Market value of livestock and poultry holding	657.1982	718.511
CHARINC	Profit from charcoal sales	64.761	182.341
NONAGINC	Nonagricultural income	403.052	551.527
CREDIT	Amount of loans taken in 2011	56.600	145.313
	Observations	704	

Table 2.3: Descriptive statistics for household model variables

Variable		Tobit Mean	Tobit St. Dev.	Production Function Mean	Production Function St. Dev.
DISTPLOT	Average walking distance to plots	27.048	30.040	26.853	29.247
LANDSIZE	Total household land	1.123	0.825	1.093	0.879
SOILPOOR	Fraction of land with poor soil	0.108	0.293	0.097	0.289
TITLE	Fraction of land with title	0.194	0.369	0.177	0.359
FLAT	Fraction of land considered flat	0.525	0.448	0.509	0.447
IRRIGATE	Fraction of land under irrigation	0.069	0.217	0.070	0.218
LIVEFRAC	Fraction of land with live barriers	0.211	0.379	0.192	0.369
SEKFRAC	Fraction of land with mi sék	0.113	0.293	0.131	0.315
PYEFRAC	Fraction of land with kodon pyé	0.112	0.299	0.107	0.296
HHDIVERS	Household crop Gini-Simpson index	0.552	0.215	0.560	0.214
MALEKARO	Males (>12) per karo	3.210	3.708	3.129	3.726
FMALEKRO	Females (>12) per karo	3.164	3.919	3.123	3.992
CHILDREN	Number of children (12 or younger)	1.515	1.399	1.742	1.617
HIRELAB	Man days of hired agricultural labor	-	-	20.422	270.660
CONVIT	Man days of communal agricultural labor	-	-	18.839	50.684
HOHAGE	Age of head of household	47.321	13.941	44.346	18.286
HOHEDU	Years of household head education	2.927	3.430	3.094	3.455
HHSICK	Average number of household days sick/month	0.801	1.735	0.820	1.817
DISTMARK	Distance to nearest market	2929.46	2349.725	2735.342	2151.266
ANIMALS	Market value of livestock and poultry holding	594.084	677.011	579.141	621.480
CHARINC	Profit from charcoal sales	60.507	197.255	61.281	205.131
NONAGINC	Nonagricultural income	403.856	539.621	396.165	501.677
CREDIT	Amount of loans taken in 2011	55.464	157.822	56.624	157.142
CROPINC	Total income from agricultural production	350.323	460.869	353.674	489.183
Observations		371		383	

Table 2.4: Probit model results for households in Central Haiti for three categories on SWC practices

Variable	Live Barrier (*t*-value) Partial Effect	Live Barrier (*t*-value) Coefficient	Mi sék (*t*-value) Partial Effect	Mi sék (*t*-value) Coefficient	Kodon Pyé (*t*-value) Partial Effect	Kodon Pyé (*t*-value) Coefficient
PLTDIST	4.4×10^{-4} (1.18)	.002 (1.17)	-1.3×10^{-4} (-.41)	-8.1×10^{-4} (-.41)	7.2×10^{-4} (2.65)[c]	.004 (2.61)[c]
LANDSIZE	.009 (.40)	.034 (.40)	-.008 (-.42)	-.046 (-.42)	.009 (.55)	.055 (.55)
PLOTSIZE	-.036 (-.79)	-.138 (-.79)	-.010 (-.27)	-.061 (-.27)	-.011 (-.43)	-.089 (-.43)
PSOILPR	.092 (1.64)	.333 (1.72)[a]	-.033 (-.89)	-.219 (-.80)	.019 (.45)	.112 (.47)
PLTTITLE	-.019 (-.50)	-.078 (-.35)	.113 (3.03)[c]	.563 (3.49)[c]	-.076 (2.94)[c]	-.529 (2.47)[b]
PLTFLAT	-.176 (-5.19)[c]	-.657 (-5.12)[c]	-.102 (-3.98)[c]	-.625 (-3.89)[c]	-.118 (-4.62)[c]	-.726 (-4.39)[c]
PLOTIRR	-.015 (-.24)	-.061 (-.24)	.059 (.94)	.311 (1.05)	-.049 (-1.02)	-.337 (-.88)
PLTDIVER	.125 (2.06)[b]	.482 (2.04)[b]	.085 (1.78)[a]	.509 (1.78)[a]	.042 (.87)	.255 (.87)
MALEKARO	-.014 (-1.48)	-.053 (-1.48)	,002 (.35)	,012 (.35)	-.022 (-2.51)[b]	-.131 (-2.50)[b]
FMALEKRO	-.029 (-2.50)[b]	-.110 (-2.47)[b]	-.006 (-1.02)	-.036 (-1.02)	.006 (.86)	.034 (.86)
CHILDREN	-.009 (-.83)	-.036 (-.83)	-.004 (-.39)	-.021 (-.39)	.015 (1.76)[a]	.090 (1.75)[a]
HOHAGE	6.6×10^{-4} (.52)	.002 (.52)	-.002 (-1.79)[a]	-.011 (-1.79)[a]	8.0×10^{-4} (.83)	.005 (.83)
HOHEDU	-.006 (-1.28)	-.025 (-1.28)	-.007 (-1.68)[a]	-.040 (-1.68)[a]	-.006 (-1.50)	-.036 (-1.49)
HHSICK	-.067 (-2.97)[c]	-.259 (-2.93)[c]	.002 (.34)	.045 (.34)	.012 (1.64)	.072 (1.63)
DISTMARK	1.6×10^{-5} (2.65)[c]	6.4×10^{-5} (2.61)[c]	1.3×10^{-5} (2.69)[c]	7.5×10^{-5} (2.68)[c]	2.2×10^{-5} (4.57)[c]	1.3×10^{-4} (4.44)[c]
ANIMALS	1.2×10^{-5} (.54)	4.8×10^{-5} (.54)	-3.9×10^{-6} (-.21)	-2.3×10^{-5} (-.21)	1.2×10^{-5} (.65)	7.2×10^{-5} (.65)
CHARINC	1.4×10^{-5} (1.93)[a]	5.4×10^{-4} (1.92)[a]	-7.7×10^{-5} (-.97)	-4.7×10^{-4} (-.97)	1.6×10^{-4} (3.35)[c]	9.6×10^{-4} (3.30)[c]
NONAGINC	-1.5×10^{-5} (-.43)	-5.7×10^{-5} (-.43)	-2.5×10^{-6} (-.09)	-1.5×10^{-5} (-.09)	-2.9×10^{-5} (-.89)	-1.8×10^{-4} (-.88)
CREDIT	3.1×10^{-4} (3.24)[c]	.001 (3.18)[c]	5.1×10^{-5} (.63)	3.1×10^{-4} (.63)	3.4×10^{-4} (4.10)[c]	.002 (4.01)[c]
Log likelihood	-323.009		-214.941		-210.724	
Chi square	129.994		68.622		146.704	
AIC	686.0		469.9		461.4	

[a,b,c] represent significance at the 10%, 5%, and 1% level, respectively.

Table 2.5: Tobit model results for households in Central Haiti for three categories on SWC practices

	Live Barrier (*t*-value)		Mi sék (*t*-value)		Kodon Pyé (*t*-value)	
Variable	Partial Effect	Coefficient	Partial Effect	Coefficient	Partial Effect	Coefficient
DISTPLOT	.001 (1.11)	-.002 (1.15)	-1.2 x10^{-4} (-.32)	-.001 (-.36)	4.2 x10^{-4} (1.35)	.006 (1.40)
LANDSIZE	-.022 (-1.04)	-.106 (-1.06)	.010 (.62)	.094 (.63)	.011 (.76)	.163 (.79)
SOILPOOR	-.055 (1.11)	.262 (1.02)	-.077 (-1.46)	-.728 (-1.48)	.013 (.37)	.149 (.39)
TITLE	-.008 (-.22)	-.040 (-.22)	.050 (1.85)[a]	.456 (1.85)[a]	-.080 (-2.33)[b]	-1.151 (-2.36)[b]
FLAT	-.130 (-3.44)[c]	-.622 (-3.50)[c]	-.062 (-2.14)[b]	-.567 (-2.11)[b]	-.087 (-2.95)[c]	-1.250 (-3.08)[c]
IRRIGATE	.048 (.65)	.232 (.65)	.008 (-.14)	-.083 (-.14)	2.0 x10^{-4} (.04)	.028 (.04)
HHDIVERS	.081 (1.08)	.390 (1.07)	.061 (1.04)	.557 (1.03)	-.002 (-.03)	-.023 (-.03)
MALEKARO	-.008 (-1.07)	-.038 (-1.06)	-.003 (-.61)	-.027 (-.60)	-.017 (-2.71)[c]	-.241 (-2.40)[b]
FMALEKRO	-.026 (-3.12)[c]	-.126 (-2.79)[c]	-.028 (-.62)	-.027 (-.62)	-.002 (.43)	.030 (.43)
CHILDREN	-.018 (-1.69)[a]	-.086 (-1.69)[a]	.002 (.02)	.002 (02)	-.004 (-.53)	-.055 (-.53)
HOHAGE	-.001 (1.01)	.005 (1.01)	-.001 (-1.34)	-.011 (-1.34)	6.7 x10^{-5} (.09)	.001 (.09)
HOHEDU	-.005 (-1.01)	-.023 (-1.01)	-.001 (-.37)	-.012 (-.37)	-.002 (-1.20)	-.059 (-1.21)
HHSICK	-.059 (-2.96)[c]	-.287 (-2.63)[c]	.004 (.71)	.040 (.71)	.004 (.74)	.060 (.76)
DISTMARK	1.1 x10^{-5} (1.79)[a]	5.3 x10^{-5} (1.80)[a]	1.3 x10^{-5} (2.71)[c]	1.2 x10^{-4} (2.82)[c]	1.2 x10^{-5} (2.47)[b]	1.7 x10^{-4} (2.75)[b]
ANIMALS	6.2 x10^{-6} (.28)	3.0 x10^{-5} (.28)	-1.4 x10^{-5} (-.80)	-1.3 x10^{-4} (-.79)	6.3 x10^{-6} (.40)	9.0 x10^{-5} (.40)
CHARINC	8.7 x10^{-5} (1.41)	4.2 x10^{-4} (1.42)	-9.1 x10^{-5} (-1.06)	-8.4 x10^{-4} (-1.05)	5.4 x10^{-5} (1.44)	7.8 x10^{-4} (1.51)
NONAGINC	-3.5 x10^{-5} (-1.09)	-1.7 x10^{-4} (1.08)	-8.4 x10^{-6} (-.04)	-7.7 x10^{-5} (-.04)	-2.9 x10^{-5} (-1.09)	-4.1 x10^{-4} (-1.08)
CREDIT	1.1 x10^{-4} (1.15)	5.1 x10^{-4} (1.15)	-6.7 x10^{-5} (-.63)	-6.1 x10^{-4} (-.63)	1.5 x10^{-4} (2.65)[c]	.002 (2.91)[c]
Log likelihood	-238.189		-162.652		-158.532	
AIC	516.4		365.3		334.1	

[a,b,c] represent significance at the 10%, 5%, and 1% level, respectively.

Table 2.6: Cobb Douglas agricultural production function results for households in Central Haiti

Variable	Coefficient	SE	t-value
AVDISTPL	0.003[a]	0.002	1.73
LANDSIZE	0.397[c]	0.080	4.98
FRACPOOR	0.192	0.186	1.03
FRACTITL	0.144	0.132	1.09
FRACFLAT	0.139	0.127	1.09
FRACIRR	0.156[c]	0.046	3.38
LIVEFRAC	0.329[b]	0.141	2.34
SEKFRAC	0.098	0.174	0.56
PYEFRAC	0.583[c]	0.192	3.04
HHDIVERS	0.923[c]	0.345	2.68
MALEKARO	0.033	0.033	1.01
FMALEKRO	-0.056[a]	0.032	-1.72
CHILDREN	-0.015	0.035	-0.43
HIRELAB	0.048[c]	0.015	3.13
CONVIT	0.001	0.015	0.09
HOHAGE	-0.001	0.003	-0.45
HOHEDU	0.030[a]	0.016	1.80
DISTMARK	-1.1×10^{-4}	2.3×10^{-4}	-0.48
R^2	0.296		

CHAPTER 3

ECONOMICS OF SOIL CONSERVATION PRACTICES IN CENTRAL HAITI

3.1 Introduction

Haiti suffers from extreme soil erosion and is characterized by a large rural population farming extensively deforested and highly eroded hillsides not suited for agricultural production. As many as 40% of Haiti's hillside farms are on slopes that exceed 50% (Smucker et al. 2007). The World Bank estimated annual rates of erosion at 36.6 million tons per year under current land management practices (as cited in Jolly et al. 2007). Agricultural productivity in Haiti has been severely reduced due to erosion and other factors. Yields of maize, pigeon peas, and beans are 45%, 31%, and 70% of those in the adjacent Dominican Republic, respectively (FAO 2014).

The state of Haiti's soil resources has a strong link to poverty. Rural households rely on agriculture for a significant portion of their income, and low agricultural productivity traps many in a cycle of poverty. Approximately 70% of the country's poor live in rural areas, and two-thirds of the population are estimated to be food insecure (World Food Program 2013). The international community has helped Haiti respond to these challenges. There is a sixty-year legacy of large-scale donor-funded programs aimed specifically at the adoption of myriad soil and water conservation (SWC) practices, ranging from agroforestry to engineered structures such as rock walls (Smucker et al. 2007). In the 1980s there was a notable shift to plot-based approaches from large-scale engineered structures applied across the landscape, sometimes with little regard for the smallholder landowners. Recently, donor-funded projects have again shifted towards improving local and national watershed governance while promoting sustainable practices through market-based incentives (USAID Haiti 2014).

Many of the donor-funded projects have had limited success in establishing improved and widespread SWC practices (White and Jickling 1995). However, there are cases where the promotion by outside actors has resulted in the adoption and adaption of some SWC practices (Murray and Bannister 2004). Even without the influence of conservation programs, some indigenous SWC practices have been used in Haiti throughout its history (Bargout and Raizada 2013; Murray 1979). Today in Central Haiti and elsewhere in the country, one can find a diverse set of SWC practices in use. Some of these incorporate live plant material and can provide important sources of food, fuel, and fodder. Development practitioners often refer to these structures as ‘live’ barriers, and this convention is adopted here. Other practices use structural features such as rock walls or soil bunds and require different combinations of labor and capital to maintain. These types of structures do not directly utilize live plant material in their construction and thus are referred to as ‘dead’ barriers. Both categories of SWC practices found today in Central Haiti are a result of the traditional agricultural system, often influenced by one or more of the related programs led by outside actors. Previous research has also established that Haitian farmers often modify project-promoted hedgerows to include perennial crops that can be used for home consumption or sale (Murray and Bannister 2004).

Despite this history and the current state of agriculture, there are very few empirical studies conducted in Haiti that examine the adoption or utilization of SWC practices. Bannister and Nair (2003) examined adoption of tree-based hedgerows that were promoted as part of a series of United States Agency for International Development (USAID) funded projects between 1982 and 1991, finding that a number of household and plot characteristics were correlated with the planting of fruit trees and top-grafting. Bayard et al. (2007) examined the determinants of adoption and management of both alley cropping and rock walls, finding similar results.

These few studies on SWC practice adoption in Haiti are a subset of a much larger body of economics literature on the adoption of agricultural technologies (see Feder et al. [1985] for a thorough review). Much of the current literature on adoption centers on either one type of SWC practice or combines multiple practices into a single category. Alternatively, the adoption decision can be examined as a choice between a set of distinct management options. The SWC practices common in Haiti require different levels of capital, labor, and expertise. They also have different functional attributes that vary depending on cropping systems and plot characteristics. These characteristics often lead to a perceived and realized differentiation between practices, thereby providing the basis for the analysis of conservation behavior in Central Haiti as a choice from a set of options. A behavioral model that considers this type of framework is commonly referred to as a multinomial choice model. Examples of economic studies that have used this type of approach in different contexts and locations than Haiti include Burton et al. (1999), Bekele and Drake (2003), and Ersado (2004).

In this chapter a simultaneous decision multinomial choice framework is used to model and identify the drivers of different classes of conservation practices in Central Haiti. The utilization of live barriers, dead barriers, and the combined use of live and dead barriers is considered. The data come from a recent and novel household and plot level interview recall-based survey conducted in 2011. These surveys are common in the economics literature and follow a set of principles to minimize biases in the sample. The work represents not only the first of its kind in Haiti, but it is also one of the few studies that addresses SWC management decisions under a multinomial choice framework.

The results provide evidence that plot and household characteristics have different effects on utilization across different classes of SWC practices. Household financial assets, perceived soil quality, access to markets, and household health status are found to be significant drivers of utilization. These new insights should inform policy makers and farmers seeking better investments in conservation, and aid in the development of more profitable and sustainable agricultural systems. Given that Haiti's soil resources mimic many other developing country cases, the results are likely relevant to other locations experiencing extreme poverty due to soil degradation.

The remainder of this chapter is organized as follows. A model of household behavior based on random utility theory is presented in section 3.2, followed by the econometric specification in section 3.3. The survey methodology and descriptive statistics are presented in section 3.4. Section 3.5 contains the econometric results for the utilization of different categories of SWC practices. The last section then concludes with a discussion of implications for the design of policies related to soil conservation in Haiti and similar locations.

3.2 Household model of soil conservation practices

The agricultural household model that serves as the basis for the empirical analysis relies on a number of key assumptions common in the literature that allow proper framing of the underlying economic theory. The economics approach is based on a single representative household making decision on the use of SWC practices. In the SWC practice adoption model presented for this chapter, as in other studies of this type, the consumption side in the theoretical model is simplified in order to focus on production decisions where SWC practices are important. Because separability of production and consumption decisions holds in the data, as discussed below, the results would remain in a more complex model with differentiated labor and consumption.

In many developing agrarian-based countries, rural markets may be affected by high transaction costs or they may be non-existent. The resulting household decisions in such a situation are termed non-separable, implying that an agricultural household no longer behaves as a profit-maximizing producer, and thus production decisions can not be separated from consumption decisions (Singh et al. 1986). While non-separability has been shown in some cases of smallholder decision making in developing countries, it is reasonable to assume that it does not apply to the use of SWC practices in Central Haiti for various reasons. First, markets for labor, land, agricultural commodities, and agricultural inputs are present and complete. Central Haiti has a relatively high population density and recent and extensive investments in road infrastructure, such that markets function without significant constraints or imperfections. In the data, discussed later, it was also found that all households are indeed contracting and participating in wage labor for agricultural activities. Field observations, interviews, and survey results also support the premise that commodity and land markets are complete. For example, there is a mixed formal and customary land tenure system in the study area, and customary tenure is relatively secure. A wide range of non-labor inputs is not commonly used, but those that are used (e.g., open pollinated seeds) are easily accessed by households desiring them across the study area. Both formal or informal credit markets must also function well for the separability condition to hold, and households within the sample appear to have borrowed frequently, suggesting evidence of functioning credit markets. Lastly, households must be indifferent between the use of hired labor and their own members for agricultural production. This is expected given the wide use of hired labor purchased at market wages for production activities that are observed, and because wages are reported by all households and are uniform throughout the sample.

The remainder of this section develops a separable agricultural household model to study the use of SWC practices for Haitian farmers in the sample. The utilization of these practices is made at the household production level and is realized through changes in agricultural production of the crops in question. Although off-farm benefits such as the mitigation of the harmful effects of siltation and broader watershed protection are not considered, the household unit that is studied is the one that must be targeted if SWC practice benefits are to be fully realized. Other direct on-farm benefits such as food, fodder, and fuel are also not studied, nor do they need to be under separability to understand SWC practice use. Finally, it is important to note that SWC represents a ‘sunk’ decision for the household in that the vast majority of these practices had previously been installed prior to sampling. Therefore, current season labor and input choices are made independently of previous SWC practice adoption. This allows us to study pertinent and relevant drivers for persistent utilization of SWC practices in isolation of other complicating effects.

Consider a representative household i that maximizes its utility, represented by a continuous, twice-differentiable, and quasi-concave utility function of the form:

$$U_i = U(x_h, x_m, l; \alpha), \tag{3.1}$$

where x_h is consumption of a representative product (i.e., consumption is an index variable) produced by the household, x_m is the consumption of a representative (index) market good, and l is the amount of total household time spent on leisure.[12] The last variable α captures other exogenous factors that influence household utility. The household will maximize utility with respect to x_h, x_m, and l, subject to the following constraints:

$$T = l + L_o + L_h, \tag{3.2}$$

$$L = L_h + L_w, \tag{3.3}$$

$$y = f(L, X, \boldsymbol{D}; \psi), \text{ and} \tag{3.4}$$

[12] The i subscript is suppressed in what follows for notational simplicity.

$$p_m x_m = p_y(y - x_h) - wL_w + wL_o - p_x X - \boldsymbol{p}_D' \boldsymbol{D} + z. \quad (3.5)$$

The first constraint is a time constraint that equates household i's time endowment, T, to time spent with leisure l, off-farm wage labor by household members L_o, and time with household agricultural production L_h. The second constraint simply states the total amount of labor allocated towards production represented by L, is equal to the sum of household agricultural labor and hired labor L_w. The next constraint is a production function $f(\cdot)$, that describes production possibilities for the household and which without loss could describe production income if crop prices are used. Under this constraint, production of a representative commodity y is a function of labor time L; the types of SWC practices used as represented by the vector $\boldsymbol{D}$ (thus, D_n is an indicator that equals one if the n^{th} SWC practice is utilized); and an index variable for non-labor inputs X. Other exogenous factors that influence production such as plot slope and soil quality are captured by the variable ψ in (3.4). It is assumed conventionally that SWC practices increase production for a household that uses them, so that $\partial f(\cdot)/\partial D_n \geq 0$ and $\partial^2 f(\cdot)/\partial D_n^2 \leq 0$, for all elements D_n of $\boldsymbol{D}$. The last constraint defines the household budget, such that there is equality between the value of total consumption and cash agricultural production plus income from off-farm work and exogenous income z, minus the cost of hired labor at market rate wage w and any cost incurred for soil conservation efforts (such as maintenance) paid at the rate of $\boldsymbol{p}_d$. The elements, p_m, p_y, and p_x represent the price of the index market good, the price of the representative commodity, and a vector of non-labor input prices. The amount of own-agricultural production consumed by household i is x_h, and the marketed surplus is $(y - x_h)$.

An important element of this study is described through interpretation of p_D in (3.5). This is a vector of prices so that $\boldsymbol{p}'_D\boldsymbol{D}$ is the total cost of SWC practices utilized by the household at any point in time. The management of the SWC practices under consideration for this study is primarily interpreted as utilization rather than adoption. This distinction is made for two reasons: first, nearly all of the sampled households with soil conservation practices have used them for at least one year, and while there may be some minor modification or innovation with the application of common practices in any given year, their use has been established in the region for some time. Thus, the cost of continued utilization of conservation practices rather than the cost of establishment is represented by $\boldsymbol{p}_D$. Although some practices such as rock walls may be well established on a given plot, all SWC practices considered in this study require significant levels of annual maintenance. SWC maintenance was considered with the administration of the survey. Dis-adoption is possible for any given practice and in any given agricultural season. Dis-adoption implies that the household removes the SWC structure on their plot, and in this survey this means that the household denies use of the practice in question.

Farm profits are represented by a continuous, quasi-concave, and twice differentiable equation:

$$\pi(L, X, D; \psi) = p_y f(L, X, \boldsymbol{D}; \psi) - wL_w - p_x X - \boldsymbol{p}'_D \boldsymbol{D}. \tag{3.6}$$

As discussed above, under conditions for separability, the household model in equations (3.1) – (3.6) is recursive in that the household makes production decisions by maximizing $\pi(L, X, \boldsymbol{D}; \psi)$. Then, the maximum profits attained through these production decisions become part of the cash budget constraint that defines household utility maximization choices. The resulting first order conditions of the profit function with respect to labor L, the variable input X, and SWC practices are:

$$p_y \frac{\partial y}{\partial L} = w \tag{3.7}$$

$$p_y \frac{\partial y}{\partial X} = p_x \tag{3.8}$$

$$p_y \frac{\partial y}{\partial D_n} = p_{D_n} . \tag{3.9}$$

These conditions show that the household makes production decisions to equate marginal products for labor, inputs, and soil conservation efforts to their respective marginal costs. In other words, utilization of a given conservation practice proceeds up to the point where the cost of an additional investment is greater than its benefit in terms of increased production income. Factor demands, of which SWC practices are a subset, are derived through the first order conditions; thus the demand for D_n is:

$$D_n^* = D_n\left(p_y, w, p_x, \boldsymbol{p}_D\right). \tag{3.10}$$

Optimized levels of L, X, and the optimal SWC regime D_n^* from the factor demands are then used to define a maximized profit value as:

$$\pi^*(L^*, X^*, \boldsymbol{D}^*; \psi) = \pi^*(p_y, w, p_x, \boldsymbol{p}_D; \psi). \quad (3.11)$$

Through Hotelling's lemma and the definition of the profit function, the demand for the n^{th} SWC practice D_n can also be expressed as:

$$D_n(p_y, w, p_x, \boldsymbol{p}_D; \psi) = -\frac{\partial \pi^*}{\partial p_{D_n}}., \quad (3.12)$$

so that the decision to use the n^{th} SWC practice depends critically on expected changes in profits as well as the cost of the practice.

The indirect utility function can be derived by returning to the household utility maximization problem and defining a cash budget constraint using the maximized profit function in (3.11) to describe 'full income' M of the optimizing household:

$$M \equiv p_m x_m + p_y x_h + wl = \pi^*(p_y, w, p_x, \boldsymbol{p}_D; \psi) + wT + z. \quad (3.13)$$

The first order conditions for the decision variables x_m, x_h, and l using (3.13) and (3.1) – (3.5) are: $\frac{\partial U}{\partial x_m} = \lambda p_m, \frac{\partial U}{\partial x_h} = \lambda p_y$, and $\frac{\partial U}{\partial l} = \lambda w$, along with equation (3.13). The optimal choices solved from these conditions are defined notationally as x_m^*, x_h^* and l^*. Substituting these choices into (3.1) one arrives at a maximized value of utility (i.e., indirect utility):

$$U(x_m^*, x_h^*, l^*; a) = V[\pi^*(p_y, w, p_x, \boldsymbol{p}_{\boldsymbol{D}}; \psi) + wT + z, w; a]. \quad (3.14)$$

Equation (3.14) demonstrates how SWC management decisions enter the indirect utility function through the profit function as a component of total income.

3.3 Econometric model

This chapter considers SWC management decisions with a multinomial choice framework. In the theoretical model above, households select different levels of use for all elements D_n within the practice vector $\boldsymbol{D}$. A given management regime with intensity decisions for all SWC practices within $\boldsymbol{D}$ can be expressed as a SWC management choice for the household. The multinomial choice model in this chapter considers four distinct and exhaustive SWC management alternatives indexed as 0, 1, 2, and 3. A choice indicator variable, Y_i, is used to represent each management alternative. Define the first alternative as Y_i = 0, which is a no adoption alternative where $D_n = 0$ for all elements of D. The next two alternatives represent decisions to use either live barriers (Y_i = 1) or dead barriers (Y_i = 2) alone. The last alternative, Y_i = 3, corresponds to positive D_n values for both live and dead categories, i.e., the household chooses to utilize both in production. Modifying utility for the choice indicator variable, a simple representation of the relative expected utility demonstrates a household's choice:

$$U_{ij} > U_{ik} \tag{3.15}$$

For the purposes of the behavioral model the other elements of function (3.15) are considered fixed in the SWC decision-making process. Thus, under a multinomial choice econometric framework, equation

(3.15) describes the case concerning $\boldsymbol{D}$ where alternative $Y_i = j \in J$ is chosen over all other alternatives $k \neq j \in J$; this happens only if the household perceives itself as better off from this choice.

A multinomial logit model (MNL) is used to study the empirical realization of (3.15) in the data. The unobserved indirect utility for household i with SWC management alternative j is expressed in estimable form as:

$$U_{ij} = \boldsymbol{Z}_{ij}'\boldsymbol{\beta}_j + \varepsilon_{ij}, \quad (3.16)$$

where $\boldsymbol{Z}_{ij}$ is a vector of observed plot and household characteristics in the data with corresponding coefficients $\boldsymbol{\beta}_j$ to estimate and an error term ε_{ij}.

The plot characteristics included in the MNL model as part of $\boldsymbol{Z}_{ij}$ include those that measure the average distance to plots, the amount of cultivated land, the use of irrigation, plot slope, soil quality, land tenure, and the diversity of agricultural production. The average distance to household plots variable is included to account for potential preference towards greater investments in agricultural assets that are located closer to the household. As discussed in section 3.2, the role of land tenure in agricultural and natural resource investment decisions in Haiti has been debated over many years. The role of the tenure variable in the MNL not expected to be significant due to the established customary tenure system found in the region. It is still included to test for its potential influence. A diversity of production index variable is included in the model to capture household risk preferences. Risk averse households would be more likely to favor a more diversified production system.

The household variables included in the MNL model include those related to assets, household composition, health, and access to markets. Variables for the value of livestock holding, non-farm income, and income from charcoal production are included to account for the influence of household wealth. The average household member sick days (absent from work and other normal activities) and variables for household composition are included to allow for the potential influence of factors that might be significant drivers of adoption in the event that household consumption and production decisions are non-separable.

The probability that alternative j is chosen, i.e., observed in the data over other options, is then given by $\text{Prob}(Y_i = j) = \text{Prob}(U_{ij} > U_{ik} \big| \boldsymbol{Z}_i, \forall k \neq j)$. Using the MNL assumption, the probability that household i chooses alternative j is expressed as:

$$\text{Prob}(Y_i = j) = \frac{\exp(\boldsymbol{Z}_{ij}{}'\boldsymbol{\beta}_j)}{\sum_{j=0}^{J} \exp(\boldsymbol{Z}_{ij}{}'\boldsymbol{\beta}_j)} \qquad , j = 0,1, \dots, J. \tag{3.17}$$

Normalizing with $\beta_0 = 0$ yields:

$$\text{Prob}(Y_i = j) = \frac{\exp(\boldsymbol{Z}_{ij}{}'\boldsymbol{\beta}_n)}{1+\sum_{j=1}^{J} \exp(\boldsymbol{Z}_{ij}{}'\boldsymbol{\beta}_k)} \qquad , j = 0,1, \dots, J. \tag{3.18}$$

The coefficients of (3.18) can be estimated using maximum likelihood estimation.

There are several reasons why the multinomial econometric model is appropriate for the sample and study area in Central Haiti. First, the two groups of SWC practices used in the area, live and dead barriers, are well established in the region and therefore compose a set of SWC options that farmers must consider. Second, soil and water conservation is the perceived primary function of all of the SWC practice options. This implies that a decision to adopt a type of SWC practice follows from the consideration of all options, that is, from the household making comparisons of the type in (3.15) for Y_i = 0,1,2,3. Further, the unique characteristics of SWC practices also mean that they are distinct choices within the set of available management options. Live and dead barriers have different labor, capital, and maintenance requirements. They also differ in terms of their effects on production, and they can have unique secondary benefits that households consider and that are part of (3.15). Live barriers may require less labor to establish but can require more maintenance. Unlike dead barriers, they can also provide secondary benefits of food, fiber, and forage.

There is also a formal statistical justification for the use of the MNL model. These models operate under the assumption of independence of irrelevant alternatives (IIA), which requires that the relative odds of any two outcomes remain unchanged with the removal of any other outcomes considered in the model. This result relates directly to the condition of non-correlated error terms between alternatives, and it is the statistical underpinning of the uniqueness between alternatives discussed above. A formal test for IIA was examined for the data using the estimated MNL model and applying a Hausman-Mcfadden test (Hausman and McFadden 1984). The test results failed to reject the hypothesis of IIA for all alternatives,[13] thereby statistically supporting the use of a MNL model.

Before proceeding it is important to mention that a competing model to the MNL in these types of problems is a nested logit model, which relaxes the IIA assumption imposed by MNL and is appropriate when the Hausman-Mcfadden test fails to support IIA.[14] Finally, the specification of the MNL model was further tested using the Cramer-Ridder test (Cramer and Ridder 1991). This test compared the full MNL model as described above and an alternative MNL model where the live and dead alternatives are pooled into one outcome. The test rejected the hypothesis of the pooled model in favor of the separate

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[13] The test statistic values with the removal of the non-adoption, live, dead, and both alternatives were: -18.45, -2.00, 3.08, and 2.43 respectively. The combined live and dead SWC practice alternative was used as the base outcome to test the removal of the non-adoption alternative, and the non-adoption alternative was the base for remaining tests.

[14] Under this framework alternatives are grouped into nests, and the probability of any given outcome is contingent on the probability of the choice of a nest and the probability of the choice of the outcome between others within the selected nest. A nested logit model was also estimated to further examine the appropriateness of an MNL model. It was structured with one nest for the non-adoption alternative and one nest for the other three SWC alternatives. The results for the nested model were very close to the MNL model and the two had nearly identical log-likelihood values (-362.53 versus -364.47). Thus, based on the IIA test and the results from the nested model the MNL approach was chosen for this analysis.

live and dead categories.[15] It reinforces the SWC classification used in this study, specifically the premise that live and dead barriers should be considered distinct categories of soil conservation practices.

3.4 Data and descriptive statistics

The data used to estimate (3.18) were collected as part of a USAID Sustainable Agriculture and Natural Resource Management (SANREM) baseline survey completed between 2011 and 2012 on the Central Plateau of Haiti. A wide range of data related to demographics, heath, expenditures, natural resource management, migration, markets, and social networks was collected. The primary approach for surveying used from July to November 2011, was a one-year recall method used extensively in the economics literature. It is also based on some elements contained in the World Bank Living Standards Measurement Study survey.

A draft questionnaire was developed in collaboration with Haitian agronomists from a local non-government organization, Zanmi Lasante, and faculty in the Faculté d'Agronomie et de Médecine

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[15] The test statistic was 69.87, distributed χ^2 with 17 degrees of freedom.

Vétérinaire within the University of Haiti. Considerable attention was given to question wording and Creole translation. A pretest was completed during May and June 2011 on a sample of 30 households within the survey area. These data were not used, but the results of the pretest led to further revision of the survey instrument language and design and provided insight that aided in the development of the sampling strategy. After consultation with Zanmi Lasante and other experts familiar with the region, a sixteen-by-sixteen kilometer square centered near the town of Duffalty was identified as the primary sample area.

The sampling area contains varied topography, agronomic conditions, and socioeconomic characteristics that are largely representative of those in Central Haiti. It includes the mountain regions of Bois Joli and Balandre, the foothills of Boucane Carre and Porc Cabrit, and the lowland areas of Corporant and Grand Savane. Households and their plots varied in elevation from approximately 125 to 825 meters above sea level. Annual rainfall is around 150 cm and follows a bimodal pattern common through most of the country. The rainy season usually begins in late April and ends in November, with the highest amounts of rain during the months of May and August.

Given that high-quality imagery of Central Haiti is available through Google Earth, individual households, roads, waterways, and markets were identified for purposes of designing an area frame sampling approach. Figure 3.1 shows the outline of the sampled region with circles representing individual surveyed households.[16] The sixteen-kilometer square drawn on the Figure was divided into 256 one-kilometer square quadrats, which were subsequently used to produce a random sample of 73 one-kilometer square quadrats. A team of six Haitian agronomists, trained in survey enumeration by us, then visited all of the households within each of the 73 sampled quadrats.[17] The number sampled therefore corresponded to the density of households in order to remain representative. Coin flips were used to select whether a household was chosen for interviewing, thereby ensuring total randomness in the sampling process at the household level.

In total, 600 households were surveyed. This included information on 3,282 household members, 1,367 agricultural plots, and 3,278 plantings through a crop calendar. The refusal rate was under 2%. Definitions for the variables used in the analysis below are in Table 3.1. For most farmers in Central Haiti, the agricultural season begins in April with the beginning of the rainy season. Important crops such as corn and beans are planted during this time and harvested through the late summer. Sorghum

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[16] A more detailed map of all individual sampled households in this area is available from the authors.

[17] A total of fifteen quadrats were not visited due to logistical constraints. The omission of these sampled quadrats should not severely bias results due to the fact that the majority were either not populated and or very sparsely populated, as confirmed by satellite imagery.

(*Sorghum bicolor*) and pigeon peas (*Cajanus cajan*) are also planted with the beginning of the rainy season but they are not harvested until February and March of the following year. The household survey completed between July and November 2011, was unable to capture harvest information for all crops, particularly sorghum and pigeon peas. Households with incomplete harvest data were revisited very shortly thereafter in May 2012. These households were re-administered the agricultural modules from the 2011 survey in order complete the data set.

There are a number of SWC practices used by households within the study area, as can be seen in the results summarized in Table 3.2. The most common practice, found on 42% of all sampled fields, is the live barrier referred to as *barye vivan* in Haitian Creole. *Barye vivan* are essentially bands of live plants arranged on the contour and composed of grasses, woody plants, or perennial food crops. The most common dead barriers found within the study area are *mi sék,* which are rock walls with some degree of terracing, and *kodon pyé,* or rock walls or barriers that are less substantial than a *mi sék.* Together, *kodon pyé* and *mi sék* account for 72% of all dead barriers and 42% of all SWC practices used in the data. Other dead barriers found within the study area are *fasinaj*, *biyon, kleyonaj,* and *kanal kontou. Fasinaj* are barriers composed of dead plant material established along a contour; *biyon* are soil bunds, *kleyonaj* are barriers made using waddle construction and normally found in ravines; and *kanal kontou* are contour canals often sharing the same characteristics as *biyon*. At least one SWC practice was found in 40% of plots and with 48% of households. The combined use of different practices was only found on 17% of plots.

While the live barrier classification is composed of only *barye vivan*, the dead barrier classification is composed of the remaining six SWC practices found in the study area. Combining all types of dead barriers together could be problematic. However, as noted above, the dead barrier classification is dominated by *kodon pyé* and *mi sék*. These two practices are similar and they represent a range in the quality of rock barriers rather than two unique practices. The four other types of dead barriers share some common characteristics that may make their inclusion in the dead barriers classification reasonable.

The average length of use for a given practice was 9.5 years compared to the average period of plot ownership of 14.3 years. Households were asked from whom they learned to use the practices that are currently found on their land. By far the most common source was family at 78%. The second most frequently cited source was a non-governmental organization, but only at 10%. This fits the reality that the last major soil conservation programs in the region were implemented in the 1990s.

The timing of household observations in relation to technology introduction, the learning process, and socioeconomic dynamics are important factors in defining adoption. There are numerous examples within the literature on agricultural technology diffusion that demonstrate that different farms with different characteristics adopt at different rates and times prior to reaching a long-term equilibrium (Geroski 2000). The SWC practices examined in this chapter were affected by donor-funded projects during the 1980s and 1990s. However, the relatively long period of time since these interventions, average time of use, and transmission method all support the idea that the use of SWC practices is in long-run equilibrium. Conditions that could seriously disrupt a long-term equilibrium, such as cholera and migration from the 2010 earthquake in Port-au-Prince were not found to influence SWC practice use.

Other data are summarized in Table 3.2, which presents definitions of variables used in the econometric model, and Table 3.3, which presents various statistics concerning these variables. Included in Table 3.3 are Welch *t*-test results for adopter and non-adopter sample subsets. The average plot was approximately 0.5 karo,[18] located 28 minutes on foot from the household, and had been cultivated for 14.3 years. The average household agricultural landholding was 1.12 karo over 1.9 plots. The largest

[18] A karo is the local unit of measure and is equal to 1.29 hectares.

river in the country transects the survey area, and irrigation was found on 6.9% of agricultural land. Households were asked to classify the quality of their soil from three categories (poor, average, and good) and its slope (flat, sloped, and highly sloped): 10% of land was classified as having poor soil, and 53% was classified as flat. There was a statistically significant difference between the stated soil quality for households with and without SWC practices. Households held formal legal title to only 19% of land under management.

The primary cropping system used within the survey area is varied, primarily utilizing corn, sorghum, pigeon peas, cassava, banana, beans, and peanuts. Similar to other economic studies using data of the type that were collected, a Simpson index is used to capture the diversity of production within this intercropped system, $1 - \sum_{i=1}^{R} p_i^2$, where p_i is the fraction of the market value of the harvest for crop i compared to total harvest value (Meng et al. 1999). The index can take on values from zero to less than one. A value of zero would represent monocrop production, and values closer to one correspond with more diversified production. The average Simpson index value in the sample was 0.55 at the household level. The *t*-test shows a statistically significant difference between average levels of diversification of households that use SWC practices and those that do not. Households with SWC practices were more diversified with an average index value of 0.59 compared to 0.52 for the rest of the sample.

Households were on average composed of 5.5 members. The average head of household age was 47.3 years old, with an average of 2.9 years of formal education. Years of formal education were calculated from categorical responses from the head of household. Individuals older than 12 years old were considered part of the household's agricultural labor pool based on observations in the sample area. The average labor availability at the household-level was 3.2 males per karo and 3.2 females per karo. Straight-line distance to the nearest market was estimated using geospatial methods. Households were on average 2.93 kilometers away from the nearest major market, with SWC adopters on average further from the nearest market by a statistically significant margin. For the majority of households, markets could only be accessed on foot. It should also be noted that the location of the nearest market also corresponded with the location of the nearest health center. The population within the survey area often has to deal with chronic diseases and other illnesses. Household members missed an average of 8 days due to illness during 2011.

Average household agricultural production for 2011 was valued at $350. Income from non-agricultural activities was comparable at $403. There was however significant variation in both sources of income between households, with standard deviations of $460 and $540, respectively. Credit was readily available and households incurred loans of $55 on average in 2011, suggesting a relatively accessible informal credit market. As in other developing countries, livestock is a significant repository of wealth. Average livestock holdings, including fowl, were valued at $594.

3.6 Econometric results

The estimated MNL model is based on the following alterative choices: non-use of SWC practices, the use of only live barriers, the use of only dead barriers, and the use of both live and dead barriers. The estimated model correctly predicts 58% of outcomes, and the chi-square statistic indicates a highly significant model (Table 3.4). The number of observations reflects the fact that missing data were discarded in estimating the model. The absence of crop prices and wages as explanatory variables reflects that fact that, for the sample area, there was little variation in these variables given that households are price and wage takers.

Referring to the results (Table 3.4), the plot-related variables and the fraction of land considered flat by the household both significantly influenced SWC practice utilization in expected ways. The effect was positive for the non-use alternative, negative for the remaining three alternatives, and statistically significant for all four. The coefficient for total amount of land was significant and positive for dead barriers. This could simply be due to the existence of higher expected returns for dead barriers for at least a small parcel of land within the total holding. The more land that a household owns the higher is the probability that there is a parcel where the investment in dead barriers makes sense.

The coefficients across alternatives for the fraction of land perceived as having poor soil proved interesting. According to the estimation results, a 10% increase in the amount of poor quality land would increase the probability of the non-use alternative being chosen by 3.0%. Partial effects for the MNL model were calculated using the mean values of all explanatory variables. The effect for the dead barrier alternative was negative and significant. A 10% increase in this case would lower the probability of using a dead barrier by 3.8%. The partial effect of live barriers was positive and nearly significant (z-value equal to 1.51). These results suggest a perceived fertility enhancing function of live barriers. Non-governmental organizations in Haiti have long promoted the fertility enhancing benefits of some types of live barriers. This element of past conservation programs could partially explain the positive influence of poor soil on live barrier utilization. The result for soil quality also suggests that households view dead barriers as performing better at preventing erosion of fertile soil. The value of mitigated erosion was greater for fields that are more fertile. Therefore it is logical that a household would invest in the alternative that it sees as having the most erosion protection on fertile land. The investment can make sense on valuable fields despite the often larger upfront costs associated with dead barriers.

The estimated coefficients for the land tenure variable were not found to be significant for any of the SWC practice alternatives. These results provide evidence that the lack of a legally recognized title is not a significant deterrent to investments in conservation. The customary land tenure found in the survey area appears to function well enough to establish the land security necessary for use of SWC practices.

Of the remaining variables, credit, female labor availability, education, health, and distance to market were found to influence the utilization of some of the SWC practice alternatives. The coefficient for the use of credit was positive and significant for the option of both live and dead barriers. The coefficient for the number of adult females per karo was positive and significant for non-use, and negative and significant for both the live and dead barriers options. This could be explained by the widespread participation of women throughout the region in petty commerce. There may be a larger opportunity cost for female labor allocated to nonessential activities such as maintenance of the SWC practices. The coefficient for the education level of the household head was negative and significant for live barriers. This could be explained by higher opportunity costs for educated households who allocate time to conservation activities. The average number of sick days per month, represented by the variable HHSICK, had a negative impact on the use of live barriers. The probability of utilization by sick households decreased by 6.2% for every additional sick day per month, which is quite a significant and important finding. A sick family may be unable to allocate the required time for the levels of ongoing maintenance necessary with live barriers. This partial effect for HHSICK was positive and significant for dead barriers.

Market based variables also have interesting effects. Although wage and price did not have significant variation in the sample to be included in the model, owing to the fact households in the study area generally have the same information about prevailing market prices, other market based variables that do differ across households were found to be significant predictors of utilization for all alternatives except live barriers. The effect of a greater distance to the main market was positive for dead barriers and the combined live and dead alternatives. For every additional one kilometer a household was located from the nearest market, the probability of utilization increased by 2.4% and 1.9% for dead barriers and the combined option. This is a logical result if one considers that there are higher travel costs to participate in commodity and other markets for more distant households. This can lead to a need to be more self-sufficient, relying on one's on-farm production for a larger share of food needs. Greater care and investment in one's plot makes sense in this situation. Additionally, while agricultural labor markets are fairly complete throughout the region, there is a smaller range of jobs further away from population centers and markets. There may thus be additional household labor available to allocate towards SWC practices.

3.7 Concluding remarks

In this chapter various forms of important soil conservation practices in Central Haiti are studied, using an econometric approach that treats alternatives as simultaneous decisions and an extensive survey of smallholder households. These are most likely the first data of their type that have been collected for households in this region.

The results show that plot, market access, and household characteristics have different effects on utilization across different classes of soil practices, particularly with regard to land tenure, perceived soil quality, and household health status. These results inform the design and targeting of new programs related to soil and water conservation, such as those that include conservation agricultural practices. These results have clear implications for project targeting and natural resource management policy involving Haitian farmers, as well as similar policies for smallholder poor in other countries where soil degradation is a major cause of poverty. Projects that advocate the use of soil conservation practices must consider the unique characteristics of the households and the practices that they promote. Higher utilization rates of live barriers can be achieved by targeting households that are healthier, or investments that increase the health status of area households, especially for those that are located further from markets, have access to credit, and have plots which are perceived as having lower fertility. The results also show that public health policy can affect farm-level conservation investments. When projects promote dead barriers they must consider additional factors, such as the amount of land under cultivation. Improved access to commodity, labor, and credit markets also affects soil conserving investment decisions.

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Table 3.2: Definitions of explanatory variables used in the MNL model

Variable	Units	Description
AVDISTPL	Minutes	Average walking distance to plots
DISTPLOT	Minutes	Distance to plot
LANDSIZE	Karo	Total household landholding
FRACPOOR	Fraction	Fraction of land with poor soil
FRACTITL	Fraction	Fraction of land with title
FRACFLAT	Fraction	Fraction of land considered flat
FRACIRR	Fraction	Fraction of land under irrigation
HHDIVERS	Index (0-1)	Household crop Simpson index
MALEKARO	Men/Karo	Males (>12) per karo
FMALEKRO	Women/Karo	Females (>12) per karo
CHILDREN	Children	Number of children (12 or younger)
HIRELAB	Days	Man days of hired agricultural labor
HOHAGE	Years	Age of head of household
HOHEDU	Years	Years of household head education
HHSICK	Days	Average number of household days sick/month
DISTMARK	Meters	Distance to nearest market
ANIMALS	USD	Market value of livestock and poultry holding
NONAGINC	USD	Nonagricultural income
CREDIT	USD	Amount of loans taken in 2011

Figure 3.1: Survey area frame with sampled quadrats and households

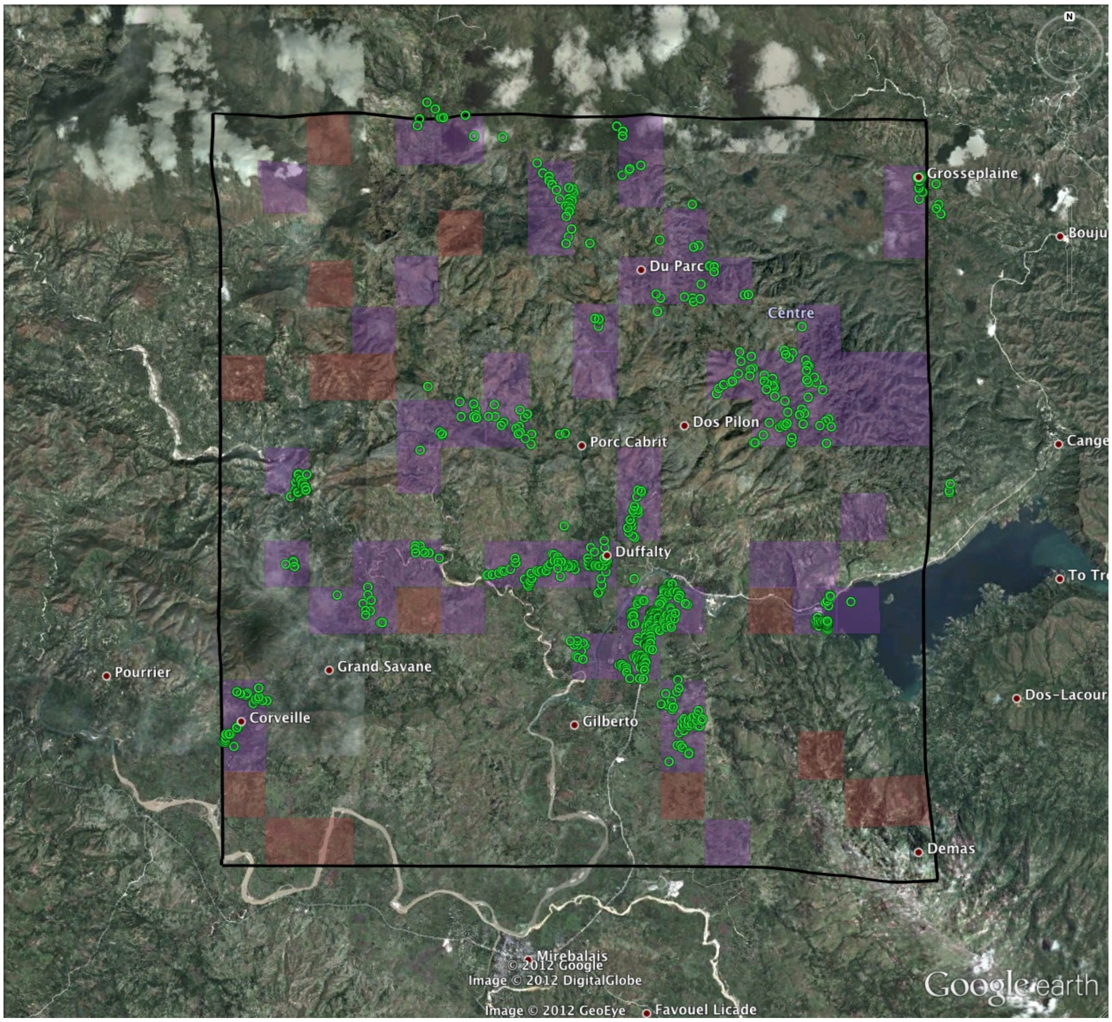

Table 3.2: Common soil conservation practices found on agricultural plots in Central Haiti.

Practice*	Classification	Incidence	Description
Barye Vivan	Live	42%	Living barrier or hedgerow
Kodon Pyé	Dead	23%	Rock barrier less substantial than a *mi sék*
Mi Sék	Dead	19%	Rock wall usually with dry wall bench
Fasinaj	Dead	7%	Trash barrier built along the contour
Biyon	Dead	5%	Soil bund or small terrace
Kleyonaj	Dead	2%	Ravine barrier that uses wattle construction
Kanal Kontou	Dead	2%	Contour canal

* The soil conservation practice categories used in this study and this table are taken from Smucker (2003).

Table 3.3: Descriptive statistics for sampled households in Central Haiti

Variable		Full Sample		Sample Grouped By SWC Use		
		Average	St. Dev.	No SWC Average	SWC Average	*t*-test *p*-value
AVDISTPL	Average walking distance to plots	27.05	30.04	23.32	31.04	0.01
LANDSIZE	Total household landholding	1.123	0.83	1.00	1.26	0.00
FRACPOOR	Fraction of land with poor soil	0.10	0.29	0.14	0.06	0.01
FRACTITL	Fraction of land with title	0.19	0.37	0.18	0.21	0.36
FRACFLAT	Fraction of land considered flat	0.53	0.45	0.71	0.33	0.00
FRACIRR	Fraction of land under irrigation	0.07	0.22	0.09	0.05	0.05
HHDIVERS	Household crop Simpson index	0.55	0.22	0.52	0.59	0.00
MALEKARO	Males (>12 years) per karo	3.21	3.71	3.76	2.62	0.00
FMALEKRO	Females (>12 years) per karo	3.16	3.92	3.86	2.41	0.00
CHILDREN	Number of children (12 younger)	1.52	1.40	1.54	1.49	0.76
HOHAGE	Age of head of household	47.32	13.94	47.05	47.61	0.70
HOHEDU	Years of household head education	2.93	3.43	3.35	2.47	0.01
HHSICK	Ave. household days sick per month	0.80	1.74	0.86	0.74	0.51
DISTMARK	Distance to nearest market	2929	2350	2244	3664	0.00
ANIMALS	Market value of livestock	594.08	677.01	600.10	587.63	0.86
NONAGINC	Nonagricultural income	403.86	539.62	450.23	354.12	0.08
CREDIT	Amount of loans taken in 2011	55.46	157.82	50.26	61.05	0.52
-	Total income from agriculture	350.32	460.87	328.19	374.06	0.34
-	Fraction of land with live barriers	0.21	0.38	0.00	0.44	0.00
-	Fraction of land with mi sék	0.11	0.29	0.00	0.23	0.00
-	Fraction of land with kodon pyé	0.11	0.30	0.00	0.23	0.00
Observations		371		192	179	

Table 3.4: Results from multinomial logit model for SWC practice utilization in Central Haiti.

	No Barrier	Live Barrier		Dead Barrier		Both Live and Dead	
Variable	Partial Effect	Partial Effect	Coefficient	Partial Effect	Coefficient	Partial Effect	Coefficient
Constant	-	-	-1.104 (-0.86)	-	-1.035 (-1.06)	-	.402 (.34)
AVDISTPL	-4.9 $\times 10^{-4}$ (-.45)	3.0 $\times 10^{-4}$ (.85)	.005 (.86)	-1.2 $\times 10^{-4}$ (-.14)	2.6 $\times 10^{-4}$ (.05)	3.1 $\times 10^{-4}$ (.66)	.004 (.68)
LANDSIZE	-.057 (-1.24)	.017 (.99)	.341 (1.24)	.064 (1.75)[a]	.382 (1.69)[a]	-.025 (-1.04)	-0.147 (-0.51)
FRACPOOR	.298 (2.08)[b]	.061 (1.51)	.404 (.65)	-.382 (-2.48)[b]	-2.26 (-2.26)[b]	.022 (.34)	-.277 (-.39)
FRACTITL	.020 (.25)	.028 (.95)	.374 (.77)	.003 (.05)	-.019 (-.05)	-.051 (-1.12)	-.533 (-1.02)
FRACFLAT	.385 (5.21)[c]	-.053 (-1.71)[a]	-1.41 (-2.92)[c]	-.231 (-3.67)[c]	-1.67 (-4.37)[c]	-.102 (-2.45)[b]	-1.63 (-3.53)[c]
FRACIRR	.042 (.28)	-.052 (-.63)	-.824 (-.64)	-.043 (-.31)	-.265 (-.32)	.053 (.71)	.445 (.53)
HHDIVERS	-.184 (-1.22)	.062 (.96)	1.21 (1.15)	.103 (.79)	.766 (.97)	.020 (.23)	.494 (.52)
MALEKARO	.004 (.38)	-.001 (-.23)	-.029 (-.29)	.008 (.91)	.029 (.54)	-.011 (-1.31)	-.120 (-1.17)
FMALEKRO	.026 (2.00)[b]	-.009 (-1.25)	-.174 (-1.43)	.010 (1.08)	.001 (.03)	-.026 (-2.67)[c]	-.299 (-2.36)[b]
CHILDREN	.013 (.58)	-.013 (-1.43)	-.218 (-1.45)	.014 (.81)	.043 (.40)	-.014 (-1.19)	-.157 (-1.17)
HOHAGE	.001 (.20)	8.2 $\times 10^{-4}$ (.87)	.011 (.71)	-.001 (-.54)	-.005 (-.46)	2.3 $\times 10^{-4}$ (-.19)	-.003 (-.22)
HOHEDU	.015 (1.55)	-.007 (-1.64)	-.132 (-1.83)[a]	-.006 (-.77)	-.053 (-1.07)	-.002 (-.34)	-.042 (-.72)
HHSICK	.050 (1.83)[a]	-.062 (-3.04)[c]	-.996 (-2.32)[b]	.044 (2.52)[b]	.116 (1.20)	-.032 (-1.49)	-.396 (-1.54)
DISTMARK	-4.2 $\times 10^{-5}$ (2.94)[c]	-7.6 $\times 10^{-7}$ (-.14)	5.9 $\times 10^{-5}$ (.65)	2.4 $\times 10^{-5}$ (2.08)[b]	1.8 $\times 10^{-4}$ (2.50)[b]	1.9 $\times 10^{-5}$ (2.72)[c]	2.6 $\times 10^{-4}$ (3.35)[c]
ANIMALS	4.6 $\times 10^{-5}$ (.94)	-9.0 $\times 10^{-6}$ (-.48)	-2.1 $\times 10^{-6}$ (-.68)	-4.9 $\times 10^{-5}$ (-1.14)	.003 (-1.13)	1.2 $\times 10^{-5}$ (.50)	4.0 $\times 10^{-4}$ (.14)
NONAGINC	3.9 $\times 10^{-6}$ (.06)	5.1 $\times 10^{-6}$ (.21)	6.8 $\times 10^{-5}$ (.17)	4.5 $\times 10^{-5}$ (.88)	1.9 $\times 10^{-4}$ (.63)	-5.4 $\times 10^{-5}$ (-1.33)	-5.3 $\times 10^{-4}$ (-1.16)
CREDIT	-2.7 $\times 10^{-4}$ (1.22)	-7.0 $\times 10^{-5}$ (-.53)	-5.8 $\times 10^{-5}$ (-.27)	1.1 $\times 10^{-4}$ (.66)	.001 (.88)	2.3 $\times 10^{-4}$ (2.51)[b]	.003 (2.38)[b]
Log likelihood	-364.469						
Chi-square	163.983						

Notes: a,b, and c represent significance at the 10%, 5%, and 1% level, respectively. z statistics are in the parentheses.

CHAPTER 4

WOODFUEL USE AND MANAGEMENT IN CENTRAL HAITI

4.1 Introduction

4.1.1 Woodfuel utilization, production, impacts, and the role of the agricultural landscape

Firewood and charcoal are indispensable resources for millions of households. More than two billion people worldwide depend on woodfuels for their daily cooking and heating needs (CIFOR 2012).[19] Most are in developing countries where access to modern energy services is limited. For example, in Sub-Saharan Africa only 68% of the population has access to electricity, and 79% rely on woodfuels and other biomass for food preparation (IEA 2013). Woodfuels account for as much as 90% of primary energy consumption in developing countries (CIFOR 2012).

The numbers are similar in Haiti, where the vast majority of households prepare their meals with woodfuel. In regions like Central Haiti, nearly all households lack access to electricity and have no option but to rely on woodfuels for energy. Charcoal and firewood may be the only affordable option, even when electricity or natural gas is available. At least 30% of household income is spent on charcoal for the average household in Port-au-Prince (Nexant 2010). The reliance on woodfuels also extends into the industrial sector. Fifty-five percent of industrial fuel consumption in Haiti comes from woodfuels (IEA 2010), and approximately 20% of all charcoal in Haiti is used for industrial purposes (Nexant and Econergy 2005). Together, woodfuels and other biomass account for 78% of total primary fuel consumption in Haiti.

[19] "Woodfuel" in this chapter refers to charcoal, firewood, and other combustible biomass directly used for household or industrial purposes unless otherwise noted.

With low barriers of entry and robust urban markets, charcoal takes on another important dimension in the rural livelihoods in developing countries. Smallholder households are the primary producers of woodfuel in most developing countries, including Haiti. One study in Haiti estimated that 16% of rural household income is derived from charcoal (ESMAP 2007). Estimates for the Central Plateau have been as high as between 21% and 30% (USAID FEWSNET 2009). Similar portions of household income from charcoal can be found in countries like those in sub-Saharan Africa (Arnold et al., 2006; Khundi et al., 2011).[20] The timing of production is also important. Charcoal use can serve as a coping mechanism in response to climatic or other idiosyncratic shocks (Zulu 2010; McSweeney 2005; Debela et al. 2012). It can also help to bridge seasonal gaps in income, or be used to offset the costs of significant household expenses, such as school fees (Kambewa et al. 2007).

While the charcoal market is an integral component of the energy sector and the broader economy in many developing countries, its production and consumption can also have significant negative impacts. On a global scale, charcoal production contributes to global warming. Some projections put the cumulative greenhouse gas emissions for sub-Saharan (the largest regional emitter of emissions) from 2000 to 2050 at nearly 15 billion tons (Bailis et al. 2005). On a more local scale, the use of charcoal and other biomass in food preparation in the home leads to serious health risks. Indoor air pollution has resulted in 4.3 million worldwide deaths in 2012, largely due to the combustion of woodfuels for household use (WHO 2014). A United Nations study [as cited in USAID (2007)] estimated that the average lifespan in Haiti has been shortened by 6.6 years from indoor air pollution. The burden of risk

[20] The large urban markets for charcoal in developing countries are expected to continue to grow. For instance, some have projected charcoal consumption to double between 2000 and 2030 in sub-Saharan Africa (Arnold et al. 2006).

from indoor air pollution is skewed towards women and children. Respiratory disease, largely from food preparation, is the largest killer of children in Haiti (Perry et al. 2005).

New evidence for some developing countries has shown that charcoal production is only a minor factor in deforestation relative to other factors, such as agricultural expansion (Arnold et al., 2003). However, in Haiti charcoal production has been a significant factor in the depletion and degradation of its remaining forest resources. This recent environmental impact of charcoal production is especially pronounced in areas with improved road infrastructure, such as the Grande Anse. The demand from urban centers, primarily Port-au-Prince, along with limited livelihood alternatives for producers drives the market. A 2007 study by the World Bank administered by the Energy Sector Management Assistance Program (ESMAP) estimated that 71,000 tons per year of charcoal could be harvested with the current production base, even though the annual demand in Port-au-Prince alone is 413,000 tons per year. The unsustainable management of Haiti's remaining forest resources for charcoal and other uses exposes households to greater risks from soil erosion and broader reductions in ecosystem services obtained from forested areas.

Haiti, including the Central Plateau, essentially has no agriculture-forest margin. With high population density and only 3.6% of land under forest cover (FAO 2014), privately managed agricultural land and its borders are an important source of both woodfuel for charcoal and firewood in Haiti. That is to say that many farmers in Haiti actively manage their woodfuel resources. The concept of active woodfuel management examined coincides with smallholder behavior as it relates to trees. There is a long-standing practice of using trees as cash crops (Murray, 1986). Tree planting, even when heavily promoted for its environmental benefits, is primarily driven by short-term economic motives (Murray and Bannister, 2004).

The agricultural landscape is an equally important source of woodfuel for charcoal in other developing countries. For example, surveys in Central Ghana revealed that the majority of charcoal is produced from trees grown on agricultural land (Amanor and Brown, 2006). In many areas woodfuels sourced from the agricultural landscape have become increasingly important with forest degradation and loss (Arnold et al., 2006). Jagar and Shively (2013) found evidence of a shift to woodfuels sourced from the agricultural landscape for household consumption in Western Uganda as a result of forest degradation and deforestation. Planted trees have also been found to be a more significant source of charcoal as a result of changes in land use and labor markets in India and Kenya (Arnold and Dewees, 1997).

4.1.2 Woodfuel related literature

The number of studies related to woodfuel and charcoal in developing countries has fluctuated over the past 40 years in conjunction with the issues and statistics that have garnered the attention of policy makers and researchers. Concerns over the overexploitation of forest resources for fuel in the 1970s and early 1980s led to targeted research and policies to address what was referred to as a “fuelwood crisis” (Arnold et al., 2003; 2006). Projections at the time pointed to global and regional market constraints, resulting in local woodfuel shortages. However, by early 1990s some of the updated projections downplayed the extent of the crisis, thereby leading to a notable decline in interest on the subject by the end of the decade.

Recently, there has been a return to concern over woodfuels and calls for a greater emphasis on the subject in both the policy and research arenas (Ghilardi et al., 2013; Sawe, 2011). Beginning in the late 1990s, projections again pointed towards potential constraints in woodfuel supplies in developing countries (Arnold et al., 2006; Mwampamba, 2007) with continued urbanization and the reexamination of energy transition theory[21] (Zulu, 2010). New research and policy initiatives for related issues such as greenhouse gas emissions and indoor air pollution have also driven the recent increase in research on woodfuels.

While much of the earlier research on woodfuels during the 1980s and early 1990s focused primarily on environmental impacts, e.g., Monela (1993) and Hoiser (1993), recent empirical studies have placed a greater emphasis on the livelihood dimensions of woodfuel and charcoal production. These efforts include those that estimate the value and profitability of charcoal production, e.g., Luoga et al. (2000). Others have estimated the opportunity costs of fuelwood for household use, e.g., Amacher (1996) and Köhlin and Parks (2001).

Discrete choice models have been used to examine a household's decision to engage in charcoal production. Khundi (2011) uses a charcoal production probit model along with propensity score matching techniques to calculate the impact of charcoal on income and poverty levels in Uganda. Similarly, Ainembabazi et al. (2013) uses a charcoal probit model with quantile regression techniques to measure the household income attributed to charcoal production. Fewer studies have focused on household behavior related to woodfuel and other non-timber forest products. One exception is Babulo (2008) who employs a behavioral study that models household dependence on charcoal and other non-timber forest products as a livelihood strategy.

There have been many studies that have looked at the determinants of tree planting at the household level. Examples include Besley (1995) and Mekonnen (2009). However, there has been less attention on the connection between tree planting and woodfuels. Gebreegziabher and van Kooten (2013) used a

[21] Energy transition theory states that households switch from woodfuels and other biomass to hydrocarbons and cleaner modern technologies with development and greater household incomes.

cross sectional household data set from Ethiopia and a two-stage Heckman selection model to identify the drivers of the decision to plant trees and the intensity of tree-related production. The same study also relates community and household tree stocks to household fuelwood consumption through demand model.

The few studies on tree planting in Haiti are primarily related to the evaluation of donor-funded reforestation and agroforestry projects. One of the main topics here has been the role of land tenure in the investment in trees and other long-term conservation related investments on farmer-managed land. Beginning in the 1980s, the commonly held view by the United States Agency for International Development (USAID) and other actors on the ground was that formal land tenure was necessary for farmers to invest in reforestation, agroforestry, or soil conservation practices. Bloche et al. (1988), Smucker et al. (2002), Bannister and Nair (2003), and others challenged these positions. They argued that the lack of formal land tenure was not a significant factor in landholders' willingness to plant trees or invest in soil conservation practices. In addition to analyzing the role of land tenure, Bannister and Nair (2003) also examined the role of other farm and household characteristics on the adoption of agroforestry practices. The authors compared the distributions of variables for adopter and non-adopter groups using non-parametric methods. The only other published empirical study on tree planting in Haiti is by Bayard et al. (2007). The authors of this study estimated a probit model for the adoption of tree-based alley cropping practices, finding evidence of the influence of different household and plot characteristics.

4.1.3 The case of Central Haiti

This chapter considers woodfuel use and management use in Central Haiti. Both the decisions to participate in charcoal production and to plant trees are considered. Probit models are complemented by parametric and nonparametric hypothesis tests between groups of producing and non-producing households. The results from the tree planting adoption model, the charcoal model, and other statistical analyses are significant contributions to the literature on woodfuel in Haiti and natural resource management. This chapter provides one of the few empirical analyses of smallholder charcoal production and tree planting in Haiti, using a recent and relatively large data set compared to previous studies. Further, although this study focuses on the Central Plateau, other countries may face similar conditions currently found in Haiti as a result of growing charcoal markets and continued environmental degradation.

The remainder of this chapter is organized as follows. The analytic methods are presented in section 4.2. Section 4.3 contains information on the survey methodology. Section 4.4 presents results from the survey and the behavioral models. This chapter concludes in section 4.5 with conclusions and policy implications.

4.2 Analytical Methods

4.2.1 Specification of the discrete choice charcoal and tree planting models

Discrete choice models for the decision to engage in charcoal production and the decision to plant trees are used and based on a random utility model framework. At the center of this framework is the assumption that households make choices to maximize their utility. Consider household i (i = 1,..,N) that faces a choice to produce charcoal and a choice to plant trees. The decision to engage in either of these activities can be indexed by a for participation, and 0, for non-participation. A household, denoted by i, will choose to participate if and only if their expected utility of participation is greater than that of non-participation: $U_{ia} > U_{i0}$. This decision for each household can be represented by a binary variable D_i, where:

$$D_i = \begin{cases} 1 \; if \; U_{ia} > U_{i0} \\ 0 \; if \; U_{ia} \leq U_{i0} \end{cases} . \tag{4.1}$$

The utility associated with decisions can be modeled as a linear combination of a vector of observable household and plot characteristics $\boldsymbol{X}$ with their associated coefficients $\boldsymbol{\delta}$ and a random disturbance term γ, such that:

$$U_i = \boldsymbol{X_i}'\boldsymbol{\delta} + \gamma_i \, . \tag{4.2}$$

The random disturbance term γ_i accounts for any measurement or specification errors concerning variables that are not observed in the data.

The probability that $D_i = 1$ can be expressed as a function of household characteristics as follows:

$$P_{ia} = \text{Prob}(D_i = 1) = \text{Prob}(U_{ia} > U_{i0}) \tag{4.3}$$

$$= \text{Prob}[\boldsymbol{X_i}'\boldsymbol{\delta}_a + \gamma_{ia} > \boldsymbol{X_i}'\boldsymbol{\delta_0} + \gamma_{i0}] \tag{4.4}$$

$$= \text{Prob}[\gamma_{ia} - \gamma_{i0} > \boldsymbol{X_i}'(\boldsymbol{\delta}_a - \boldsymbol{\delta}_0)] \tag{4.5}$$

$$= \text{Prob}(\mu_{ia} > \boldsymbol{X_i}'\boldsymbol{\beta}_a) = F(\boldsymbol{X_i}'\boldsymbol{\beta}_a) \tag{4.6}$$

where $\mu_{ia} = \gamma_{ia} - \gamma_{i0}$ is a random disturbance term, and $\boldsymbol{\beta}_a = \boldsymbol{\delta}_a - \boldsymbol{\delta}_0$ is a vector of coefficients. It is assumed that the disturbance terms γ with μ are normally distributed with a mean equal to zero. In a probit model, $F(\boldsymbol{X_i}'\boldsymbol{\beta}_a) = \Phi(\boldsymbol{X_i}'\boldsymbol{\beta}_a)$, where $\Phi(\boldsymbol{X_i}'\boldsymbol{\beta}_a)$ is a normal cumulative density function (cdf). The marginal effect of X_{ik} (the k^{th} element of $\boldsymbol{X_i}$**)** on the probability of engaging in a given activity is therefore:

$$\frac{\partial P_{ia}}{\partial \Upsilon_{ik}} = f(\boldsymbol{X_i}'\boldsymbol{\beta}_a) \times \beta_k \tag{4.7}$$

where β_k is a coefficient for X_{ik}within $\boldsymbol{\beta}_a$, and $f(\boldsymbol{X_i}'\boldsymbol{\beta}_a)$ is the value of the cumulative density function at $\boldsymbol{X_i}'\boldsymbol{\beta}_a$. The coefficients ($\boldsymbol{\beta}_a$) will be estimated using maximum likelihood estimation.

The prices of charcoal, other tree products, and related goods can play a major role in the participation decision. They are not included in $\boldsymbol{X_i}$ and their omission from the probit models is noteworthy.

However, the survey effort, discussed below, revealed that there was relative homogeneity in prices of charcoal and other key commodities across the survey area. The constancy in prices could be largely attributed to the high rural population densities and multiple linked commodity markets. The estimated models are therefore not biased as a result of this omission.

4.3 Survey Methodology

The data used to estimate (4.6) were collected as part of a USAID Sustainable Agriculture and Natural Resource Management (SANREM) baseline survey completed between 2011 and 2012 in Central Haiti. A wide range of data related to demographics, heath, expenditures, natural resource management, migration, markets, and social networks was collected. The primary approach for surveying occurred from July to November 2011 and was based on a one-year recall method used extensively in the economics literature. One exception to the one-year recall timeframe was the questions for tree planting, which asked respondents for the number of trees planted within the previous five years. The survey is also based on some elements contained in the World Bank Living Standards Measurement Study (LSMS) survey.

A draft questionnaire was developed in collaboration with Haitian agronomists from a local non-government organization, Zanmi Lasante, and faculty in the Faculté d'Agronomie et de Médecine Vétérinaire within the University of Haiti. Considerable attention was given to question wording and Creole translation. A pretest was completed during May and June 2011 on a sample of 30 households within the survey area. These data are not used, but the results of the pretest led to further revision of the survey instrument language and design and provided insight that aided in the development of the sampling strategy. After consultation with Zanmi Lasante and other experts familiar with the region, a sixteen-by-sixteen kilometer square centered near the town of Duffalty was identified as the primary sample area.

The sampling area contains varied topography, agronomic conditions, and socioeconomic characteristics that are largely representative of those in Central Haiti. It includes the mountain regions of Bois Joli and Balandre, the foothills of Boucane Carre and Porc Cabrit, and the lowland areas of Corporant and Grand Savane. Households and their plots varied in elevation from approximately 125 to 825 meters above sea level. Annual rainfall is around 150 cm and follows a bimodal pattern common through most of the country. The rainy season usually begins in late April and ends in November, with the highest amounts of rain during the months of May and August.

The sampling area contains some unique features that are relevant factors in the estimated probit estimates and the rest of the analysis that follows. The main road connecting the northern and southern parts of Haiti bisects the survey area. The road is paved and connects many in the region to important markets. However, there is notable variation across the sample area, with no other paved roads. Similarly, one of the biggest rivers in the country, the Artibonite River, follows a course in close proximity to the main road. Some farmers in the region are able to use this resource for irrigation. The Artibonite River also powers the only major hydroelectric generation facility in the country, located just within the sample area. Some households, also located primarily near the main road, are connected to the power grid and have access to electricity, albeit intermittent, unreliable, and many times prohibitively expensive.

Given that high-quality imagery of Central Haiti is available through Google Earth, individual households, roads, waterways, and markets were identified for purposes of designing an area frame sampling approach. Figure 4.1 shows the outline of the sampled region with circles representing individual surveyed households. The sixteen-kilometer square drawn on the figure was divided into 256 one-kilometer square quadrats, which were subsequently used to produce a random sample of 73 one-kilometer square quadrats. A team of six Haitian agronomists, trained in survey enumeration, then visited all of the households within each of the 73 sampled quadrats.[22] The number sampled therefore corresponded to the density of households in order to remain representative. Coin flips were used to select whether a household was chosen for interviewing, thereby ensuring total randomness in the sampling process.

In total, 600 households were surveyed. This included information on 3,282 household members, 1,367 agricultural plots, and 3,278 plantings through a crop calendar. The refusal rate was under 2%. Definitions for the variables used in the analysis below are in Table 4.2. For most farmers in Central Haiti the agricultural season begins in April with the beginning of the rainy season. Principal crops such as corn and beans are planted during this time and harvested through the late summer. Sorghum and pigeon peas are also planted in the beginning of the rainy season, but they are not harvested until February and March of the following year. The household survey completed between July and November 2011 was unable to capture harvest information for all crops, particularly sorghum and pigeon peas. Households with incomplete harvest data were revisited very shortly thereafter in May 2012. These households were re-administered the agricultural modules from the 2011 survey in order complete the data set.

The set of explanatory variables captured by the survey and constitute the vector $\boldsymbol{X_i}$ from equation (4.6) include household variables related to access to markets, demographics, assets, and agricultural production (Table 4.1). A variable measuring elevation (in meters) above sea level accounts for varied access to some types of resources, and to some degree, different growing conditions that may influence participation decisions. Households located further from markets may have higher transaction costs for

[22] A total of fifteen quadrats were not visited due to logistical constraints. The omission of these sampled quadrats should not severely bias results due to the fact that a majority were either not populated or very sparsely populated, as confirmed by satellite imagery.

goods and services, and this variation is captured by the variable MARKET. Household demographic variables for the number of inhabitants, head of household (HoH) age, HoH education, HoH gender, and the number of children are also potentially important factor. They have been shown to influence the quantity and quality of household labor, agricultural skill, and the nature of household expenditures. The degree of diversification in agricultural production can reflect risk preferences and perhaps household dependence on own production, both of which can be significant drivers in activity choice. A variable for a Simpson Index is used to capture the diversity of crop production: $1 - \sum_{i=1}^{R} p_i^2$, where p_i is the fraction of the market value of the harvest for crop i compared to total harvest value (Meng et al., 1999). The index can take on values from zero to less than one. An index value of zero represents monocrop production, and values closer to one demonstrate a more diverse production system. Variables related to household assets including those for the value of livestock[23], income from non-agricultural activities[24], the amount of loans taken in 2011, the percentage of land with legal title[25], total household land holding[26], and the number of agricultural plots are also included. All of the explanatory variables described above have been shown to be significant drivers of household behavior in a wide range of relevant activity choice and technology adoption studies.

[23] The value of livestock holding is calculated from an average market value across all households for a particular species.

[24] Income from non-agricultural activities includes all sources excluding sales of agricultural commodities grown by the household, woodfuels, and credit.

[25] The possession of legal title was established by asking respondents if a given parcel was *ak papye*, or with paper (title). This may include inherited and undivided parcels with title.

[26] Household landholding includes rented land.

4.4 Results

4.4.1 Household woodfuel production and consumption

Forty-three percent of households used electricity over the previous year. Despite the fact that many were connected to the electrical grid, all surveyed households used only fuelwood and charcoal to prepare their meals. The non-use of electrical appliances in the preparation of meals could be attributed to unreliability electrical service, costs, and cultural preferences for alternatives.

Across all households, an average of only 14% of meals were cooked with charcoal. The remainder was prepared with fuelwood and an open three-rock fire. Nearly half of all households used fuelwood exclusively, and only two percent used charcoal exclusively. Yet as shown below, many households produce charcoal and it is widely available in local markets. The dominance of fuelwood for household use, even by charcoal producing households is a pattern that has been documented in Haiti and in other developing countries (Angelsen and Wunder, 2003). In rural areas charcoal is primarily a commodity sold for urban consumption while fuelwood is used within the home.

Fuelwood was identified by respondents as harvested from land belonging to a given household, land with open access, or a combination of these two sources. Individual collection sites of each type were named, along with how often they were utilized and the travel time on foot. Open access areas represented over half of all identified fuelwood sites across the entire sample (57%). Thirty-three percent of the remaining fuelwood sites were on land managed by the household and 10% were categorized as mixed. Households traveled longer distances to open access sites, with an average to 35 minutes travel time on foot. Collection sites on household land were five minutes closer and mixed sites were located only an average of 18 minutes from the household. While open access collection sites are more common, fuelwood sites owned by the household were visited much more often. Those that collected fuelwood reported that sites owed by the household were used an average of 6.0 times per month, open access sites were visited 6.6 times per month, and mixed sites only 2.0 times. From these results, it is clear that both land managed by the household and open access sites play an important role in domestic fuelwood supplies in the region. Fuelwood harvesting often occurs on agricultural land, and household woodfuel management decisions may include decisions on fuelwood supplies.

Forty-five percent of households reported that they made charcoal in 2011. This is much higher than the national average of 21% of agricultural households published by the Government of Haiti (MARNDR 2012). An average of 9.5 sacks[27] was produced across all households. Among the 45% who made charcoal in 2011, the average was 21.2 sacks during the sample period. The process of woodfuel harvesting of conversation to charcoal was a job primarily completed by male heads of the household. As with other agricultural commodities in Haiti, women play a much more significant role in the subsequent marketing of charcoal further along the supply chain.

In contrast to fuelwood, survey results indicate that land managed by the households is the principal source of woodfuel for charcoal. Agricultural land with secure tenure[28] accounted for approximately 90% of charcoal feedstock collection sites, and was the source for 94% of all charcoal produced in 2011. Only 1.5% used exclusively open access lands and 7.4% used both common and private land. Charcoal feedstock collection sites that were owned by the household were located closer to the household. While these results suggest a strong connection between woodfuel and private land, there could be some measurement error. Charcoal collection from land owned by the state or others likely plays a greater role than these results indicate. Respondents could be reluctant to report charcoal

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[27] The *gros sac* or large sack commonly found in Haiti is the unit of measure for charcoal in this chapter. It weighs approximately 35 kg when full.

[28] Land with secure tenure is defined here as land with title or land owned by the household through divided inheritance.

woodfuel collection sites that are not their own. Nevertheless, it is safe to say that household land plays a major role in charcoal production.

The relation between charcoal and privately owned land and other household characteristics is further revealed through hypothesis tests between households that produce charcoal and those that do not. Due to the skewed nature of the distributions of many of the variables of interest, Wilcoxon rank-sum tests are used for the hypothesis tests of central tendency in addition to Welch's *t*-tests.[29] There were significant differences in the average land holding under cultivation and total landholding (including fallow plots) between charcoal and non-charcoal groups, as can be seen in Table 4.2. On average, charcoal producing households had 0.258 additional *karo* under cultivation and 0.195 additional *karo* of total land holding. The results from Welch's *t*-tests lead to a rejection of the hypothesis in favor of the alternative: the sample means for both variables for charcoal producing households were greater than non-charcoal producing households. The Wilcoxon rank-sum test yields a similar result, and both tests show a high-level of statistical significance. The difference in quantity of land managed by charcoal and non-charcoal producing households along with the finding that the vast majority of charcoal is produced on private land strengthens the case for active woodfuel management by farm households.

The results presented in Table 4.2 reveal additional differences between charcoal producing and non-producing groups. Charcoal producing households are on average located at higher altitudes and further away from markets. This sheds additional light on the importance of charcoal production as a livelihood strategy. Households located further from other income generating opportunities may rely more on charcoal. The diversity of crops grown was measured with a Gini-Simpson index, which could be considered a proxy for risk preferences. The results show that on average, charcoal producers grow a

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[29] Shapiro-Wilk tests were performed for all variables, and rejected the normality null-hypothesis in all cases.

more diverse set of crops. Income from charcoal can be used to diversify income and mitigate risks; the same way that diversified production would in theory reduce the variance in agricultural returns.

The hypothesis tests contained in Table 4.2 also allow examination of differences in income and assets between charcoal producing and non-charcoal producing households. In some cases, charcoal production has been associated with households among the poorest cohorts (Zulu and Richardson, 2013). Other studies have found evidence to the contrary (Khundi et al., 2011). The hypothesis tests for the value of livestock and agricultural income result in a failure to reject the null hypotheses of equal means (or central tendency with the Wilcoxon test) between groups. This outcome does not support either position that charcoal is a livelihood strategy primarily for poorer or for wealthier agricultural households. The result provides some basis for the examination of participation in charcoal production separate from other household decisions, such as cropping decisions. The one-sided *t*-test and Wilcoxon one-sided test for non-agricultural income failed to accept the null hypotheses in favor of the alternative: charcoal producing households earn on average, or at the median, less non-agricultural income than non-charcoal producing households. Charcoal production, rather than other non-agricultural activities, serves as an important secondary source of income for many rural households. The results of the hypothesis tests support this characterization.

Health and education expenditures can represent a major expense for rural families in Haiti. Research has shown that charcoal revenues are often used to offset these costs and to cope with household shocks caused by unforeseen illnesses (Arnold et al. 2006). Sample data only permitted an analysis of total health expenditures, and the hypothesis tests did not reject the hypotheses of significant differences of mean and central tendency in health expenditures between groups. Although, the case against rejecting the null hypothesis may have been heavily influenced by the wide distribution in reported 2011 expenses, as seen by the reported sample standard deviation. Similarly, a significant difference in the average number of children was not found between groups.

Several household characteristics influence the decision of whether or not to participate (Table 4.3). Additional years of education for a head of household were found to have a negative effect on participation. For every additional year in school the probability of production decreased by 1.5%. The occurrence of a male head of household increased the probability of charcoal participation by 14.5%. Both of these results agree with similar charcoal models developed in Ainembabzi et al. (2013) and Khundi et al. (2011).

The probit estimates in Table 4.3 also includes the amount of (exogenous) non-agricultural income earned in 2011. This income can include employment wages and income earned from commercial activities (excluding own agricultural production and tree products). The probit estimates show that non-agricultural income has a negative effect on participation, albeit with a lower level of significance. This result speaks to the role that charcoal plays as an alternative livelihood strategy. Households without other sources of income may be more likely to participate in charcoal production.

Perhaps the most interesting result from the probit estimates is the coefficient for household land. The coefficient for the total amount of land owned by the household, itself a sunk exogenous variable in the analysis, was positive and significant at 95%. Participation increases by approximately 10% for every additional karo of land managed by the household. This is contrary to the findings of Ainembabazi et al. (2013) and Khundi et al. (2011). Both of these studies found that more household land reduced the probability of participation in charcoal production for farmers in rural Uganda.

The divergence of results could be at least partially attributed to land availability. The households used in the Ugandan studies were located in charcoal producing districts with access to state-owned lands and privately owned forests. While some charcoal in the region was made from wood sourced from private land, public lands accounted for a major portion of the charcoal produced. The study area in

Haiti is different in that there are no intact forests and no tracts of public lands with large supplies of wood to make charcoal. Private land, often also used for agriculture, is an essential factor of charcoal production in Haiti. Additional land holding in a situation like the one found in Uganda may increase the opportunity cost of additional labor used for charcoal production in favor of agriculture. Households may be less likely to utilize labor to actively manage forest resources for woodfuel given the use of open access areas and higher agricultural productivity. In Haiti, with high population density, scarcity of open access feedstock, and relatively low agricultural productivity, additional landholding could incentivize the allocation of some land towards woodfuel. Additional land in Haiti could also offer more space for cultivating trees on the margins of plots, thereby increasing the supply of woodfuel that could be used to produce charcoal. The importance of household land in charcoal production is again demonstrated by the probit estimates, and reinforces the idea that Haitian smallholders actively manage woodfuel resources.

4.4.2 Tree planting and woodfuel management

The results presented above show that woodfuel for charcoal is primarily sourced from privately owned land, that the ownership of more land increases the probability of production, and that there is a common link between charcoal production and fuelwood for households in the sample. Tree planting on household land is a common practice in Central Haiti, and there is also a clear link with woodfuel management. Tree planting on private land and fuelwood use has been examined in other studies, although it has never been examined rigorously in Haiti. Some of the questions that are explored this section are, which species are most commonly planted; what are the determinants of tree planting; and what differences in tree planting behavior can be seen between charcoal producing and non-producing households?

In the data, approximately 43% of all households surveyed planted trees between 2006 and 2011. The breakdown of planting by species can be seen in Figure 4.2 and Figure 4.3.[30] The most commonly planted fruit species was mango. Some of the motivation behind widespread mango cultivation can be found in robust local markets and growing international markets for local varieties. Mango is also the principal source of lumber in Haiti, and it is widely utilized for fuelwood and charcoal in Central Haiti (Timyan 1996). Other fruit tree species can play a role in woodfuel supplies, but they fall far short in importance to mango.

The most frequently planted non-fruit species include *chenn*, *delen*, *fwenn, kajou*, and *kasya*. Catalpla logissima, commonly known in Creole as *chenn* and in English as Haitian oak, was the most frequently planted non-fruit species across the sample. *Chenn* is not primarily used for charcoal. Its wood is more valuable as lumber. *Delen* (*Leucaena leucophala*) *fwenn* (*Simarouba glauca*), and *kasya* (*Senna siama*) are fast-growing species often associated with agroforestry practices. They are commonly used both for firewood and charcoal. *Kajou* or mahogany is harvested for lumber but it is also sometimes used for charcoal.

Although the survey instrument did not capture the locations where trees were planted, it is reasonable to assume that the vast majority of trees were planted on private land. This assumption is based on the dominance of private land relative to the scarcity of commonly managed areas and the importance of trees in local agricultural practices and securing tenure in the absence of formal title.

The relationship between household land and charcoal production is considered in the hypothesis tests contained in Table 4.2. Privately managed household land was the primary area used for both charcoal

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[30] The species in Figure 4.2 and Figure 4.3 are identified by their common Creole names. Their scientific names and commonly used English names are listed in the Appendix.

production and tree planting. The presence of these two related activities on household land provides some evidence of woodfuel management by smallholders in Central Haiti.

The influence of household characteristics on tree planting behavior can be seen through the probit estimates presented in Table 4.4. An older head of household leads to a greater probability of tree planting. For every additional year of head of household age, the probability of planting increased by approximately 0.5%. The diversification of agricultural production as represented by the DIVERSITY variable also had a positive and significant effect on tree planting. Diversified production could be viewed as a proxy for risk preferences. It is logical that more risk averse households would prefer to allocate land and labor towards tree resources that can be used as additional sources of income and harvested in times of need. Lastly, additional plots under management significantly increase the probability of tree planting. An important, connection could be made between charcoal production and tree planting when considering the effect of additional household land in the charcoal probit model. Additional household land in the charcoal model resulted in a greater likelihood of participation in production. The positive effects of more land and plots on both charcoal participation and tree planting are consistent with the concept that tree planting is used as a woodfuel management strategy.

The nature of woodfuel management and the potential role of tree planting by smallholders in Central Haiti are further examined through the hypothesis tests presented in Table 4.5. Households are once again divided by charcoal participation. The groups are analyzed with respect to the variables for fruit tree plantings, non-fruit tree plantings, and the planting of any tree species. Due to the highly skewed nature of the distribution for plantings, non-parametric Wilcoxon rank-sum tests are again used for hypothesis tests of central tendency. Wilcoxon rank-sum tests are performed with all values of a given variable, in addition to tests on only positive values. The differences in participation rates between groups (represented by the fraction of non-zero values within a group) are also of interest. The results from both one- and two-tailed Pearson's chi-square tests of independence are given in Table 4.5 to gain insight into these differences.

The mean number of fruit tree species planted over the past five years was 7.4 for charcoal producing households compared to 1.9 for those that did not participate in charcoal production. Mean plantings of any species was 16.3 for charcoal participants and 4.7 for non-participants. Two-tailed Wilcoxon tests confirm that there is a statistically significant difference between the two groups, and one-tailed tests confirm with a high-level of significance that charcoal producers planted more fruit tree species and more planted more of all tree species combined. The chi-square tests show a significant difference between groups for the fraction of households that plant fruit species. Both the fraction of households that planted fruit tree species and the fraction of households that planted any species were found to be significantly greater for the charcoal producing group through the one-tailed chi-square test.

While all species are multiuse and fruit trees have the obvious benefit of fruit for consumption and for sale, it is important to note the importance of mango as a feedstock for charcoal. Mangos were the dominant fruit species planted by sampled households (see Figure 4.2), accounting for approximately 42% of all fruit plantings. At the very least, planted mango represents potential future feedstock for charcoal. Mango planting decisions by many households are likely intentionally made for the joint production of woodfuel and fruit.[31]

The mean number of non-fruit species planted by charcoal producing households was less than the mean for non-charcoal producing households. This is a result that contrasts those for fruit species and all species combined. Again, the distribution for non-fruit species plantings is highly skewed, and

[31] The examination of rotation age under a joint production framework was not possible with the data available.

outliers within the non-charcoal group have heavy influence on the mean. A more accurate picture of the difference in non-fruit species plantings between groups can be obtained through the Wilcoxon rank-sum test and the comparison of the fractions of non-zero values. The one-tailed Wilcoxon rank-sum test nearly rejects the null hypothesis in favor of the alternative hypothesis that the rank-sum of plantings for the charcoal group is greater than that of the non-charcoal group. Nearly 40% of charcoal producing households planted non-fruit species compared to only 30% for non-charcoal producing households. The one- and two-tailed chi-square tests show significant differences in the fraction of households that planted trees and support the hypothesis that a higher fraction of charcoal producing households plant non-fruit trees.

The use of SWC practices, measured by the fraction of household land managed with these practices, is examined the same way as the tree planting variables. The fraction of household land managed with soil conservation barriers that incorporate live plant material (referred to as live barriers) and those without vegetation (referred to as dead barriers) also exhibit skewed distributions with high concentrations of zero-values. The hypothesis tests do not suggest a difference between the distributions of dead barriers for charcoal producing and non-charcoal producing groups. The one- and two-tailed tests (with the exception of the Wilcoxon tests for non-zero values) for live barriers do however show statistically significant differences between groups.

Charcoal producing households had an average of 25% of their land under live barriers, while non-charcoal producing households had an average of 18%. Thirty-two percent of charcoal producing households used live barriers compared to only 22% of non-charcoal producing households. The one-tailed Wilcoxon tests support the hypothesis of a greater intensity of use of live barriers for the charcoal producing group, and the one-tailed chi-square points to a higher fraction of adopters within the same group. The greater use of live barriers by charcoal producing households could be due to use of potential charcoal feedstock (e.g., fast-growing leguminous species) within live barriers.

4.5 Conclusions

Empirical results that suggest a relationship between charcoal production and tree planting was in Central Haiti were presented in this chapter. Charcoal producing households were found to have planted more trees than non-producing households. The other empirical methods rely on the role of privately managed land to make the connection between charcoal and tree planning. Survey statistics indicate that that the majority of woodfuel used to produce charcoal is grown on household land rather than areas with open access. The charcoal probit estimates also point to the influence of private land on charcoal production decisions, with a 10% increase in the probability of participation with every additional karo of land under management. The tree planting probit estimates revealed a similar positive effect of household land on planting decisions. Examined together, these findings support the position that tree planting and charcoal production decisions are part of a woodfuel management strategy used by many households in Central Haiti.

The probit estimates also reveal additional drivers of the charcoal and tree planting decision-making processes. Household characteristics such as head of household education, gender, and levels of income from non-agricultural sources were found to significantly affect the decision to participate in charcoal production. For tree planting, head of household age, the level of crop diversification, and the number of plots were all found to have a positive and significant effect.

The woodfuel sector, and especially charcoal, often lacks reliable data, and as a result, the ability to develop and support informed policy has historically been limited (Chidumayo and Gumbo 2013). Haiti is no exception. The findings presented in this chapter offer insights into the charcoal and woodfuel sector in Haiti. Given the lack of accurate information on the subject, the results are highly relevant for policy formation. The charcoal probit estimates offer valuable insight into some of the household characteristics that must be considered in order to influence production decisions. For example, the probability of engaging in production decreases significantly with an increase in income from non-agricultural activities. Labor market development in rural charcoal producing regions, such as Central Haiti, would therefore likely have a negative effect on charcoal supplies. The data also show that charcoal is supplied but not utilized by households in the region. Population centers, such as Port-au-Prince, are heavily dependent on charcoal and other woodfuel for their primary energy needs. Policy that influences labor markets in charcoal producing regions could therefore have an influence on energy consumption in other parts of the country. Given the apparent woodfuel management that is occurring on household land, policies related to tree planting and agriculture will also have an effect on energy supplies. Policies that subsidize or promote tree-planting activities have the potential to increase charcoal supplies. There is often an environmental motivation behind these types of policies. In fact, they could be counterproductive to broader environmental goals if a reduction in the price of charcoal and other woodfuel makes them more competitive to relatively environmentally friendly fuel options, such as liquid natural gas.

While this chapter offers important information on woodfuel and woodfuel management in Central Haiti, there are a number of related areas that can be addressed with future research. First, the value of woodfuel production was not thoroughly examined in this study. Clearly, charcoal has an important impact on rural livelihoods in the region, and any policy that might influence production would need to understand the degree to which livelihoods would be affected. Woodfuel production functions would provide these kinds of estimates. Second, while evidence for woodfuel management was provided, information on the multiple uses of planted trees and the role of charcoal feedstock from coppicing were not considered due to data constraints. The woodfuel management decisions related to specific plantings, including coppicing over time, would provide a more complete view. Lastly, the interplay between agriculture and woodfuel management could be examined further. With limited fallow household land, crops and trees are often grown in the same plots. Targeted research on the supply of woodfuel, the supply of related agricultural commodities, and their interaction would shed additional light on how agricultural policies impact woodfuel management and vice versa.

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Table 4.1: Definitions of explanatory variables used in the participation decision estimation.

Variable	Units	Description
ALTITUDE	Meters	Household elevation above sea level
MARKET	Meters	Straight-line household distance to nearest market
HMEMBER	People	Number of household members
HOHAGE	Years	Age of head of household
HOHEDU	Years	Years of household head education
HOHSEX	Dummy Var.	Gender of head of household (1 if male)
CHILDREN	Children	Number of children (12 or younger)
DIVERSITY	Index (0-1)	Household crop Simpson index
ANIMALS	USD	Market value of livestock and poultry holding
NONAGINC	USD	Non-agricultural income
CREDIT	USD	Amount of loans taken in 2011
TENURE	Fraction	Fraction of land with legal tenure
LAND	Karo	Total household land holding
PLOTS	Plot	Total number of household land plots

Figure 4.1: Area frame and sampled households in Central Haiti

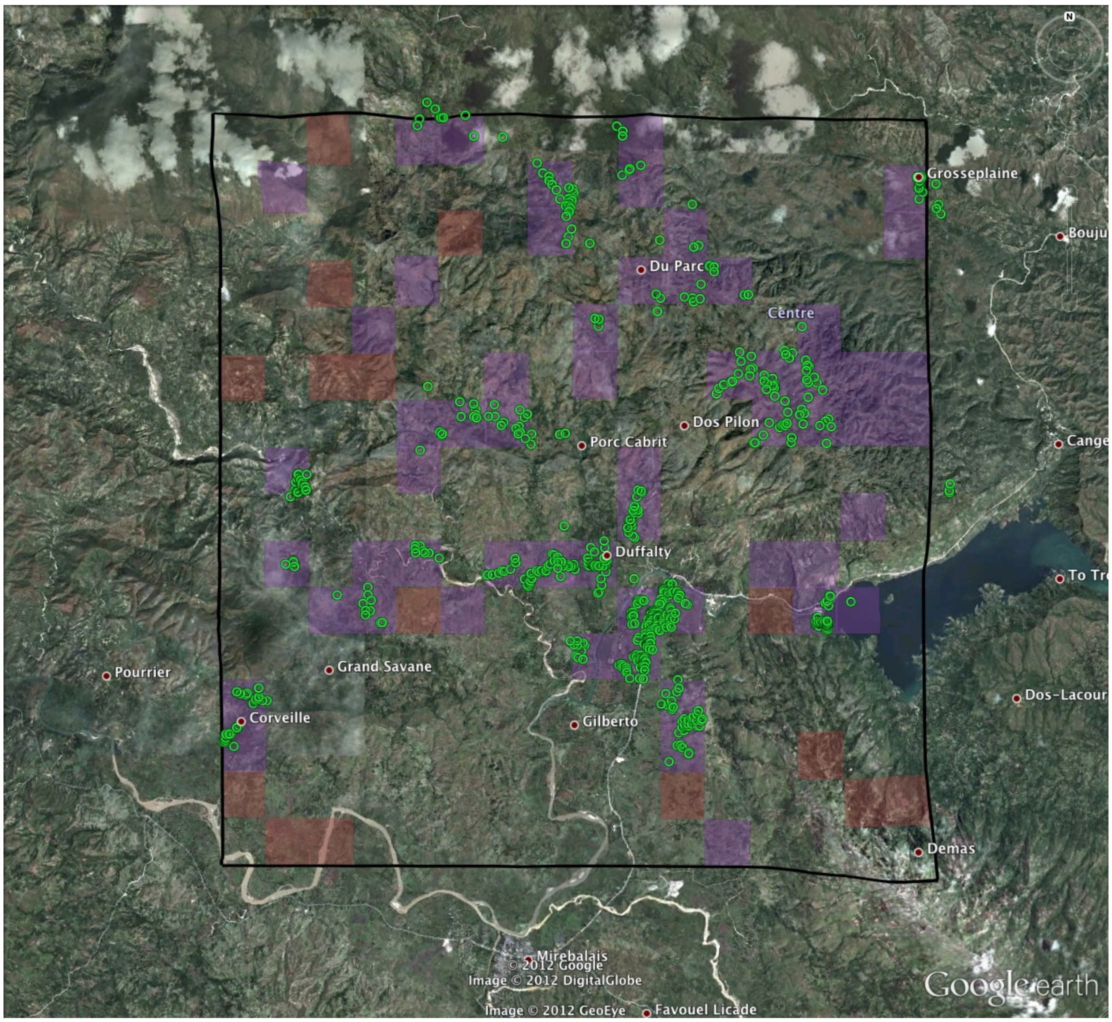

Table 4.2: Hypothesis tests for means of selected variables between charcoal and non-charcoal producing household

	Full Sample		Difference in Means ($\mu_{\mathrm{C}} - \mu_{\mathrm{NC}}$)[a]	Alternative Hypothesis	Welch's t-Test p-Value	Wilcoxon rank-sum test p-Value
	Average	StDev				
Household altitude	285.158	210.801	44.890	$\mu_{\mathrm{C}} > \mu_{\mathrm{NC}}$	0.012	0.003
Distance to nearest market	2972.847	2371.17	491.753	$\mu_{\mathrm{C}} > \mu_{\mathrm{NC}}$	0.019	0.010
Health expenditures per month	78.719	191.280	-18.334	$\mu_{\mathrm{C}} \neq \mu_{\mathrm{NC}}$	0.255	0.293
Number of household members	5.448	2.343	0.081	$\mu_{\mathrm{C}} \neq \mu_{\mathrm{NC}}$	0.716	0.794
Number of children (12 younger)	1.677	1.569	-0.007	$\mu_{C} \neq \mu_{NC}$	0.964	0.699
Household crop Simpson index	0.581	0.190	0.034	$\mu_{C} > \mu_{NC}$	0.029	0.008
Land under cultivation	0.996	0.716	0.258	$\mu_{C} > \mu_{NC}$	$7.91\text{x}10^{-}$	$3.39\ \text{x}10^{-5}$
Total land holding	0.762	0.565	0.195	$\mu_{C} > \mu_{NC}$	1.67	$4.78\ \text{x}10^{-4}$
Market value of livestock	585.022	656.099	19.747	$\mu_{C} \neq \mu_{NC}$	0.747	0.297
Agricultural Income	337.652	425.882	33.012	$\mu_{C} \neq \mu_{NC}$	0.413	0.047
Non-agricultural income	399.940	532.934	-127.196	$\mu_{C} < \mu_{NC}$	0.005	0.005
Fraction of land with title	0.206	0.380	-0.005	$\mu_{C} \neq \mu_{NC}$	0.881	0.880

[a] μ_{C} refers to mean for the *t*-test for the charcoal group or the sum of ranks for Wilcoxon test for the charcoal group. μ_{NC} refers to the non-charcoal group

Table 4.3: Probit results for charcoal production

Variable	Coefficient	Std. Error	p-Value	Partial Effect
Constant	-0.84460[a]	0.34326	0.00244	-
ALTITUDE	0.00011	0.00045	0.77691	4.4×10^{-5}
MARKET	2.8×10^{-5}	4.1×10^{-8}	0.59345	8.6×10^{-6}
HMEMBE	0.02865	0.03260	0.33890	0.01077
HOHAGE	-0.00179	0.00372	0.99899	-0.01461
HOHEDU	-0.03888[b]	0.01919	0.03849	-0.01461
HOHSEX	0.39315[b]	0.16557	0.01394	0.14528
CHILDRE	-0.03669	0.049012	0.45344	-0.01379
DIVERSIT	0.40888	0.33311	0.16203	0.15365
ANIMALS	2.5×10^{-6}	9.94×10^{-5}	0.99890	9.1×10^{-7}
NONAGIN	-0.00021[a]	0.00012	0.06598	-8.1×10^{-5}
CREDIT	0.00046	0.00049	0.32506	0.00018
TENURE	0.03317	0.16348	0.95105	0.01247
LAND	0.26733[b]	0.10923	0.03539	0.10046
Log likelihood		-		
LR χ^2 (13)		31.02766		
McFadden Psuedo R^2		0.04920		

Notes: a, b, and c represent significance at the 10%, 5%, and 1% level, respectively.

Figure 4.2: Plantings of tree species used primarily for fruit from 2006 to 2011

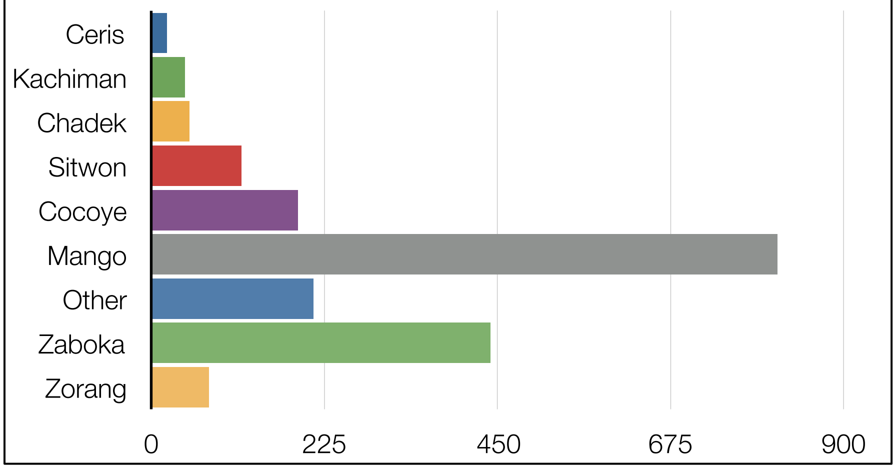

Figure 4.3: Plantings of tree species used primarily for wood from 2006 to 2011

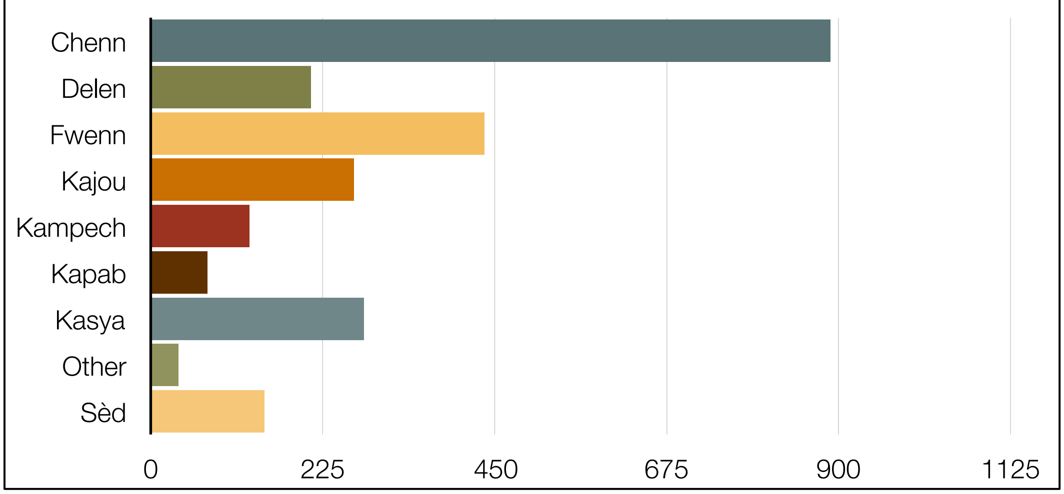

Table 4.4: Probit results for tree planting

Variable	Coefficient	Std. Error	p-Value	Partial Effect
Constant	-2.01389	0.37911	-5.31205	-
ALTITUDE	0.00027	0.00046	0.57598	$9.7x10^{-5}$
MARKET	$-3.9x10^{-5}$	$4.1x10^{-5}$	-0.93966	$-1.4x10^{-6}$
HMEMBER	0.01014	0.03280	0.30911	0.00371
HOHAGE	0.01193[a]	0.00385	3.09706	0.00436
HOHEDU	0.01112	0.01933	0.57514	0.00496
HOHSEX	0.16960	0.16543	1.02520	0.06157
NUMCHILD	-0.02526	0.04983	-0.50690	-0.00923
DIVERSITY	1.53842[a]	0.35771	4.30080	0.56221
ANIMALS	$8.1x10^{-5}$	$9.8x10^{-5}$	0.83031	$3.0x10^{-5}$
NONAGINC	$3.8x10^{-6}$	0.00013	0.03007	$1.4x10^{-6}$
CREDIT	$8.1x10^{-6}$	0.00049	0.01664	$3.0x10^{-6}$
TENURE	-0.14404	0.16484	-0.87383	-0.05264
PLOTS	0.17482[c]	0.09867	1.77173	0.06389
Log likelihood		-292.6747		
LR χ^2 (13)		44.53361		
McFadden Pseudo R^2		.0707		

Notes: a, b, and c represent significance at 10%, 5%, and 1% respectively.

Table 4.5: Tree planting and soil conservation practice hypothesis test between charcoal and non-charcoal producing households

	Mean		Fraction of Non-Zero Values		p-Value (Test for Char > No Char)			p-Value (Two-tailed test)		
	Char. Group	No Char	Char. Group	No Char	Pearson's χ^2 for fraction of non-zero values	Wilcoxon rank-sum test with all values	Wilcoxon rank-sum test with non-zero values	Pearson's χ^2 for fraction of non-zero values	Wilcoxon rank-sum test with all values	Wilcoxon rank-sum test with non-zero values
Fruit trees planted	7.439	1.896	0.395	0.293	0.013	0.002	0.006	0.027	0.005	0.013
Wood trees planted	3.429	7.292	0.395	0.300	0.021	0.139	1	0.043	0.278	3.9×10^{-5}
Any trees planted	16.337	4.660	0.488	0.408	0.054	0.001	7.9×10^{-6}	0.107	0.003	1.6×10^{-5}
Fraction land w/ live barriers	0.253	0.180	0.317	0.224	0.017	0.014	0.485	0.033	0.027	0.970
Fraction land w/ dead barriers	0.220	0.215	0.288	0.276	0.431	0.410	0.608	0.862	0.820	0.788

Table 4.6: Common cultivated tree species in Central Haiti

Haitian Name	Scientific Name	Common English
	Species Grown Primarily for Fruit	
Ceris	*Malpighia emarginata*	Barbados Cherry
Kachiman	*Annona genus*	Pawpaw
Chadek	*Cirtus maxima*	Pumelo
Sitwon	*Citrus aurantifolia*	Key Lime
Kokoye	*Cocos nucifera*	Coconut
Mango	*Mangifera indica*	Mango
Zaboka	*Persea americana*	Avocado
Zorang	*Citrus sinensis*	Orange
	Species Grown Primarily for Wood	
Chenn	*Catalpa logissima*	Haitian Oak
Delen	*Leucaena leucophala*	Leucaena
Fwenn	*Simarouba glauca*	Paradise Tree
Kajou	*Swietenia mahogoni*	Mahogany
Kampech	*Fabaceae genus*	Various
Kasya	*Senna siama*	Kassod Tree
Sèd	*Cedrela odorata*	Spanish Cedar