Shady Business: Why do Puerto Rican Coffee Farmers Adopt Conservation Agriculture Practices?

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Abstract

Coffee is grown in some of the most biologically diverse regions of the world. Sometimes, coffee farming causes significant environmental damage, but with certain cultivation practices, coffee farms can support a wide range of forest biodiversity. According to a recent survey, the majority of coffee farmers in Puerto Rico report using these practices to *some extent* while also participating in programs favoring the use of practices that are more harmful to the environment.

This paper is an exploratory exercise seeking to shed light on the forces driving farming practices in Puerto Rico, and identify important channels of action for the Department of Natural and Environmental Resources of Puerto Rico to induce farmers to adopt agricultural conservation practices. Specifically, this paper addresses the following question: what makes coffee farmers in Puerto Rico choose a shaded plantation over a non-shaded or *sun* plantation?

Paradoxically, the results suggest that receiving assistance from state programs favoring less sustainable, mono-crop systems is the most important driver of the decision to adopt environmentally beneficial agricultural management practices. A plausible explanation for this counterintuitive finding is that coffee farmers in Puerto Rico try to remain eligible to receive benefits from conservation programs as well as yield-oriented programs by keeping many types of cultivation in their farms.

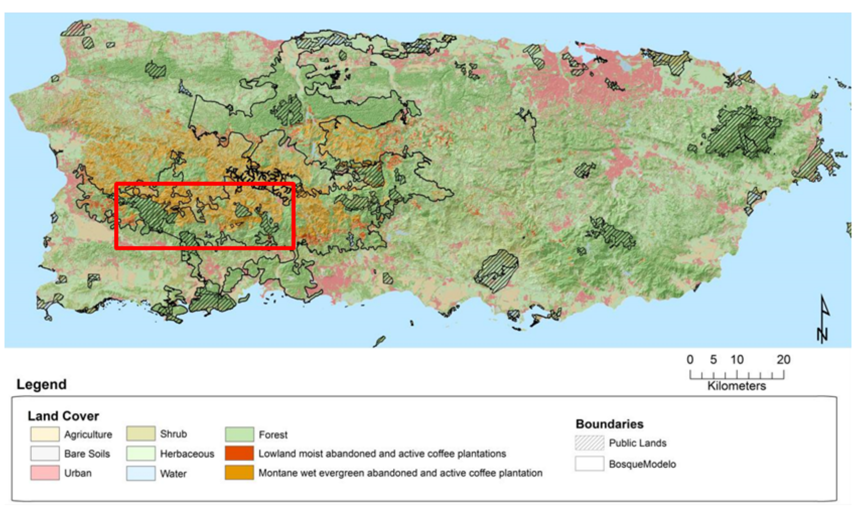
Ultimately, the case of conservation incentives programs in Puerto Rico seems to be one of good intentions accompanied by poor oversight and a high degree of mis-coordination, all factors that enable a form of rent-seeking among coffee farmers in PR. Federal environmental agencies interested in improving the targeting of existing programs should be wary of displacing or even duplicating the efforts from antagonistic state programs that favor a monocrop-type of coffee cultivation, as ironic as this may seem. Instead, conservation agencies may consider devoting their resources to alternative routes that also induce adoption of conservation practices. For instance, encouraging the creation of shade coffee certification programs or supporting other means for improving farmer access to gourmet markets, high-end retailers and high-value consumers.
Keywords: Conservation Agriculture, Payments for Ecosystem Services, Shade Coffee, Puerto Rico
JEL Codes: Q15, Q28, Q58

1 Introduction

The Department of Natural and Environmental Resources of Puerto Rico (PR DRNA) is tasked with protecting, conserving, developing and managing the natural and environmental resources of the island. Among its conservation objectives, the DRNA seeks to ensure the long-term persistence of key habitats in the island as well as their resident species of birds and amphibians. In 2013, the DRNA mandated as part of its new habitat conservation strategy an 87 percent increase in the area of protected habitats in the island. This increase constitutes a growth in conserved forested area by 62,250 hectares, or a change from 8 percent to 15 percent of the island's area.

To meet its expansionary objective, the DRNA has put in place land acquisition programs of key forested lands mostly located in the central south-west regions of the island (See Figure 1 provided by Centro para la Conservación del Paisaje, CPP, in 2015). Between 2010 and 2015, 16,450 hectares of forested lands where protected through acquisitions by the DRNA and approximately 480 hectares were protected through conservation easements (Puerto Rico Forest Action Plan, 2015).

Figure 1: DRNA Target Area (CPP, 2015)



Interestingly, the focal area of the DRNA's conservation plan is also the strongest coffee production region of the island. This coincidence provides the DRNA an attractive opportunity to increase the conservation habitat without going over budget by promoting the use of conservation agro-ecological practices. The DRNA would avoid the costs of buying or leasing all 62,250 hectares of land for conservation if it were able to successfully incentivize coffee farmers to adopt agricultural conservation management practices.

There are grossly two methods for managing a coffee plantation: farmers can produce coffee under a diverse and dense canopy of shade trees or grow the coffee trees without a shade cover. The coffee produced in a system with shade trees is often refer to as *shade coffee*, while its counterpart is called *sun coffee*. There is an inherent trade-off for coffee growers, where the demand for sustainable and ecologically-friendly cultivation practices comes at the expense of forgone short-term productivity.

According to a recent survey, over 80% of coffee farmers were beneficiaries of state-lead programs promoting sun coffee cultivation. However, over 65% of farmers in the survey also reported growing shade coffee in their farms, suggesting there exist economic benefits for farmers from shade coffee cultivation (CCP, 2015). This paper is an exploratory exercise seeking to shed light on the forces driving farming practices in Puerto Rico, and identify important channels of action for the DRNA to induce farmers to adopt shaded plantations to focus their resources. Specifically, this paper poses the following questions: (1) what makes coffee farmers in Puerto Rico choose a shaded plantation over a sun plantation; and (2) how big an incentive would be necessary to nudge them into changing from one to the other.

To answer the first question, I develop a micro-econometric model that takes data from a random sample of commercial farmers in the coffee-producing region of Puerto Rico. I examine the profile of farmers to determine both, the factors affecting land-owner participation in a variety of biodiversity conservation, and other, sometimes conflicting, land management programs. I also assess the performance of these schemes based on how likely participating farmers are to adopt conservation practices. Answering the second question entails knowing the ecological functions of coffee farm systems and the social value of the ecosystem services produced in coffee farms. Therefore, it remains a question for future research. However, I conduct a theoretical exercise to shed some light into what could be expected from such an investigation.

The empirical results indicate that participation in state-lead, sun-oriented, farm management programs increases the probability of using conservation agriculture practices in spite of them not explicitly targeting ecological outcomes, supporting the hypothesis of there being positive profits in shade coffee farming. Additionally, the results suggest that farmers who participate in conservation programs encouraging the cultivation of coffee under shaded canopies are *newer*, or less experienced, farmers who take advantage of quality differentials in their product and sell it in specialty markets. In turn, the findings suggest that farmers who are more likely to adopt shade-management practices may also be *privileged* farmers in the sense that they are more likely to have attained higher levels of education. These farmers may, therefore, have access to additional sources of income that allow them to afford becoming producers of shade coffee.

Paradoxically, based on the studied sample, receiving benefits from state programs favoring mono-crop systems is the most important driver of the decision to adopt environmentally beneficial agricultural management practices. A plausible explanation for this counterintuitive finding is that coffee farmers in Puerto Rico try to remain eligible to receive benefits from conservation programs as well as sun-oriented programs by keeping both types of cultivation in their farms. This interpretation is consistent with the finding that leaving undeveloped forest land in the farm is an important and significant determinant of program participation, and with the enigmatic survey responses where 65% of farmers report growing shade coffee to some extent while 80% participate in programs favoring the cultivation of sun coffee.

This paper is organized as follows: section 2 provides background information on the particular policy context facing coffee farmers in Puerto Rico. In this section, I describe the conflict between conservation mandates established by Puerto Rico's Department of

Natural Resources, and productivity objectives made explicit by the territory's Department of Agriculture. Section 3 describes the data used in the empirical analysis. Section 4 lays out the theoretical framework for examining adoption decisions, and connects insights from the theoretical discussion with empirical methods used to deal with the data at hand. In section 5, the results from the empirical analysis are discussed and summarized. Finally, this paper concludes with a section on implications for policy-makers and conservation activists.

2 Background

Coffee is an important commodity traded internationally. It is produced and exported by approximately 55 countries most of which belong to low and middle income regions of the world. The largest world producing region is Central and South America, with many of the leading world producers like Brazil, Colombia, and Mexico. Other important producers in the region are Peru, Guatemala, El Salvador, and Costa Rica (Cooper, 2014). As far as production in North American countries goes, coffee plants grow commercially only in U.S. territories of Hawaii and Puerto Rico.

The coffee tree is an evergreen tropical plant which grows in the tropics between latitudes 25° North and 25° South. The tropical climate required for coffee production often dictates that coffee producing regions are also valuable landscapes for biodiversity conservation and ecosystem service provision. Sometimes, coffee farming causes significant environmental damage, but with certain cultivation practices, coffee farms can support a wide range of forest biodiversity. Hence, in the last three decades, environmentalists and ecological activists have become increasingly supportive of policies that encourage the adoption of conservation-oriented agro-ecosystem management practices.

There are grossly two methods for managing a coffee plantation: farmers can produce coffee under a diverse and dense canopy of shade trees or grow the coffee trees without a shade cover. The coffee produced in a system with shade trees is often refer to as *shade coffee*, while its counterpart is called *sun coffee*. Shade coffee plantations have the potential to function as natural forests in regards to their capacity for biodiversity conservation and carbon sequestration, among the production of other ecosystem services. However, the use of sustainable and ecologically-friendly cultivation practices comes at the expense of forgone short-term productivity.

Worldwide, there seems to be a recent trend towards the reduction in usage of shade cover within coffee plantations as this management practice proves economically unsustainable despite its superior capacity for ecosystem services provision (Jha et al., 2014). Sun plantations are more economically attractive to coffee growers in the short run, as sun-grown coffee trees are believed to produce higher yields than shade-grown trees. Additionally, the forested structure of a shade farm makes it difficult to implement mechanized harvesting technologies. As the harvesting of shade plantations relies primarily on labor, this management practice creates an additional dependence for coffee producers on the state of the labor market and the availability of complementary or substitutable inputs.

The apparent increase in farms of sun monoculture has inspired concern among conservation agencies and in recent years, several campaigns have been launched to promote the production and consumption of shade-coffee through various market and non-market mechanisms. One of the emerging strategies is shade coffee certification. Shade-coffee certification seeks to compensate farmers for the biodiversity conservation service provided by their shaded plantations. Another policy instrument that is increasingly popular for the conservation and sustainable management of natural resources are schemes of Payments for Ecosystem Services (PES). PES are economic incentives offered to farmers or landowners in exchange for managing their agricultural and forest lands to provide some sort of ecological service.

2.1 Coffee production in Puerto Rico and its agro-ecology

The focus of this paper is the impact of conservation-oriented, incentive policies on farm management practices among coffee growers in Puerto Rico. Puerto Rico produces only a small fraction of the coffee it demands. Once a strong coffee producer with large markets in both the U.S. and Europe, Puerto Rico's coffee sector has been in sharp decline in the last decades, with growers increasingly leaving the coffee business and abandoning coffee farms. Figure 2 shows a time series of area harvested, tons of coffee produced and coffee yield in Puerto Rico between 1961 and 2012.

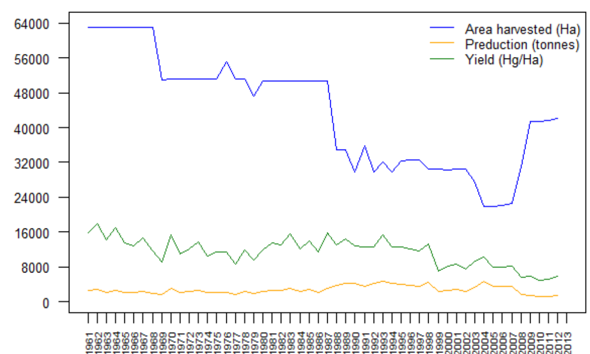


Figure 2: Coffee Production in Puerto Rico (FAO, 2015)

The contraction of the industry is undeniable. Since 1990, production has fallen by 63% and total land area devoted to coffee has declined more or less by half (from 32,114 ha to 15,144). In this period of time, the land devoted to shade coffee decreased nearly by 80% while cultivated sun coffee area increased by 65%, as shown by figures 3-4. Figure 3 shows farmland devoted to shade and sun coffee between 1980 and 2007, and Figure 4 shows total number of coffee farms growing shade and sun coffee in the same time period.

There is reason to suspect that the decline in coffee production is related to many structural causes related to structural characteristics of Puerto Rico's economy. Large up-front costs, a tight labor market, sluggish markets for fertilizer and seeds, pest emergence, market failures linked to high transportation costs and presence of monopsonistic power, and output market rigidities could be among the obstacles facing coffee growers.

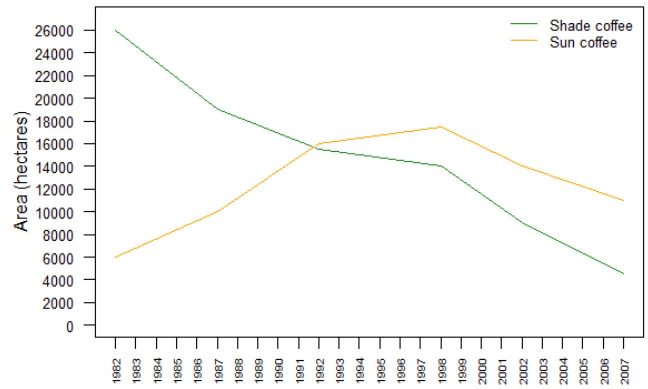


Figure 3: Farmland Under Shade and Sun Coffee. (USDA Census)

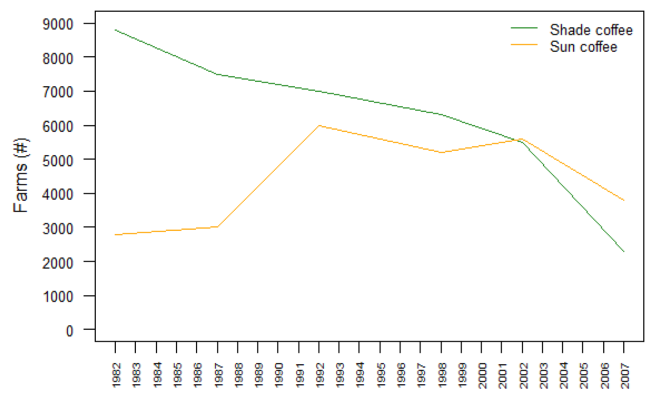


Figure 4: Farms Growing Shade and Sun Coffee. (USDA Census)

Given the contraction of the coffee sector, for the past 50 years or so, the Department of Agriculture of Puerto Rico (PRDA) has focused policies affecting coffee farmers around the objective of increasing yields. To fulfill this mission, the DA has put in place various schemes that encourage coffee farmers to take up intensive farming of sun varieties that produce higher yields. Currently, to encourage sun coffee cultivation, the government uses subsidy programs and conditional insurance terms. Government subsidy programs include conditional cash transfers and in-kind assistance programs in which farmers receive fertilizer or pesticides. They also include economic aid for investment in specialized machinery, distribution of fertilizers and pesticides, access to extension services, and wage subsidies to reduce the costs of labor to farmers. Finally, the PRDA offers more attractive insurance products to growers of sun-coffee as the institutional perception is that the canopy providing shade in plantations imposes an additional risk to the coffee plants during catastrophic events (e.g. hurricanes).

Government programs seemed to have had certain success as shown by Figures 3-4. The apparent increase in the number of farms that practice sun monoculture has inspired concern among conservation agencies. The botanical diversity contained in shaded coffee agro-ecosystems is said to provide shelter for a high biodiversity of other organisms, including birds and amphibians, and is therefore considered better for the environment. Without auxiliary shade trees, sun coffee plantations support fewer native species, store less carbon, experience higher levels of erosion, and leach more nutrients. They also require more resources such as water and fertilizers. Other ecosystem services such as pollination and pest control are purportedly generally greater in shaded coffee farms (Borkhataria et al., 2012). Table 1 compares Sun and Shade Coffee production on various performance indicators. This information was obtained from a report on Mexican Shade Coffee presented to the World Trade Organization by Consumer's Choice Council in 2002.

Since the early 2000's a consortium of conservation organizations that includes the Natural Resources Conservation Service (NRCS) and the US Fish and Wildlife Service (USFWS) has been involved in restoring the shading canopy in coffee plantations in the island. The restoration project in Puerto Rico focuses on promoting the transition from sun to shade coffee among farmers by providing the shade trees, funds and technical assistance. Under the NRCS and USFWS subsidy program, farmers are required to convert at least a third of their farm to shade. Beneficiaries receive the shade trees for free and some fixed amount of money (USD $8) per tree planted. The number of trees a farmer receives depends on the land that is converted to shade coffee. Also, the support is only offered once, upon adoption.

It is unclear whether federal programs targeting biodiversity conservation have been successful at nudging farmers to transition from sun to shade cultivation practices. A

Table 1: Comparison of Shade and Sun Coffee Plantations

	Shade	**Sun**
Production		
Yield	Lower (∼25-40%)	Higher
Plants/Hectare	1000-2000	3000-7000
Kg/Ha/Year	550	1600
Lifetime of Plants	24-30	15-Dec
Side Crops	High	
Flavor	Less Bitter	
Producers	Mostly, small-scale growers	Mostly, large-scale growers
Costs		
Weeding	Lower	Higher
Chemical Fertilizer	Lower	Higher
Pesticides	Lower	Higher
Irrigation	Lower	Higher
Labor*	Higher	Lower
Ecology		
Soil Erosion	Lower	Higher
Soil Acidification	Lower	Higher
Toxic Run-Off	Lower	Higher
Biology		
No. of Bird Species	150	20-50
Proportion Avifauna	3-Feb	∼1/10
Mid-size Mammals	24 species	∼0
Other	More species	Less species

* Not included in the original table.
Source: Seattle Audubon Society Shade-Grown Coffee Project available here: http://dnr.wi.gov/wnrmag/html/stories/2004/feb04/shadechart.htm

preliminary review of a 2015 socioeconomic survey distributed by Puerto Rico's Centro para la Conservacin del Paisaje (CCP), shows that 18% of farmers do not participate in any of the incentive programs (for sun or shade), 29% receive subsidies for cultivating both sun and shade coffee, 50% receive only PRDA (sun) incentives and 3% receive only federal (shade) incentives. According to this survey, the most popular incentive program is the PR Department of Agriculture's fertilizer subsidy program with 93% of participants applying and receiving benefits from this program, followed by the wage subsidy program (53%), the assistance for new sun coffee farmers (48%), the NRCS shade coffee program (27%), and the DA's subsidy for returning sun farmers (13%). Table 2 summarizes the results from the CCP survey. It shows the percentage of respondents that receive benefits from a particular agency.

Table 2: Program Participants by Provider Agency. Source: CCP Surveys, 2015

USFWS	NRCS	PRDA	NRCS+PRDA	USFWS+PRDA	PRDA+NRCS+USFWS
0%	1%	60%	30%	3%	6%

The primary objective of the study presented here is to investigate the factors that determine farmer participation in conservation programs and the impact of said programs on adoption of conservation practices in Puerto Rico with the objective of providing useful information to DRNA regarding the effectiveness of the programs in achieving the agency's objective of expanding the conserved area of key forest habitats by 62,250 hectares.

There is a broad consensus within the literature that adoption and diffusion of conservation practices are the result of a complex decision-making process, particularly when examined at the micro-economic level. Those decisions have been found to depend on a wide array of agro-ecological factors, such as habitat fragmentation, spatial configuration of agricultural lands, farmer demographics and political, cultural and economic institutions of a particular social environment, among others.[1] For the particular case of Puerto Rico, little research has been done about the status of coffee production, the influence of governmental policies on farming practices and the attitudes of farmers towards sustainable production practices. The most recent study on farming practices and attitudes towards conservation was conducted by Borkhataria et al. (2012). The findings in this paper suggest that farmers prefer to grow shade coffee but grow sun coffee to qualify for incentives established by Puerto Rico's Department of Agriculture. These survey results are perhaps a stretch on their own, but are in general consistent with the findings from the econometric analysis conducted here. In the following sections I describe the data used for the empirical analysis and then discuss the methodologies used to arrive at the results that are thoroughly discussed and evaluated in the final sections of this paper.

[1]See for example, Lawler et al., 2014; Lewis and Wu, 2014; Lewis, 2010; Lin, 2010; Polasky and Segerson, 2009; Lewis, Plantinga and Wu, 2009; Nelson et al., 2008; Lewis and Plantinga, 2007.

3 Data

In 2013, after the publication of its new strategy for habitat conservation, the DRNA selected a group of researcher to conduct a comprehensive study to guide the Department's decisions regarding the allocation of funds and efforts to meet the agency's goal of increasing the island's conserved forest area from 8% to 15% and to target this increase in the coffee producing region of the island, where most wet forest habitats are found.

Between 2013 and 2015, an interdisciplinary team of state, federal, academic and NGO agencies gathered data to determine the "optimal area of influence"of the project.[2] The optimal area was defined as the patch of private land that performed best at (1) maximizing the area within the *Bosque Modelo*;[3] (2) maximizing the area of natural conservation areas already protected; (3) hosting secondary wet forest habitats (priority habitats); and (4) being located where the dominant economic activity is coffee agriculture. The final selection of land consisted of 44,174 hectares (18,076 short of the DNRA's target). Then, a socioeconomic survey was distributed to a random sample of coffee farmers within the selected area. Figures 5-6 show the final target area of the project and the randomly selected sites where the interviews were conducted.

The CCP was the organization in charge of the socioeconomic investigation and between September and December of 2015 it conducted 89 interviews to randomly selected commercial coffee farmers from the target area as shown by figure 6. The sample included 124 coffee farms in 12 municipalities in the west-central region of Puerto Rico: Adjuntas, Ciales, Guayanilla, Jayuya, Juana Diaz, Lares, Las Marias, Maricao, Ponce, Sabana Grande, Utuado and Yauco.

The average age among surveyed farmers was 59. About a third of respondents had

[2] These agencies are North Carolina State University (NCSU), the South East Climate Science Center (SECSC), PR Department of Agriculture (PRDA), the US Fish and Wildlife Service (USFWS), the National Resources Conservation Service (NRCS), and Puerto Rico's Centro para la Conservación del Paisaje (CCP) and Casa Pueblo

[3] The *Bosque Modelo* is a political definition proposed by the International Model Forest Network that distinguishes of certain forested zones in the island.

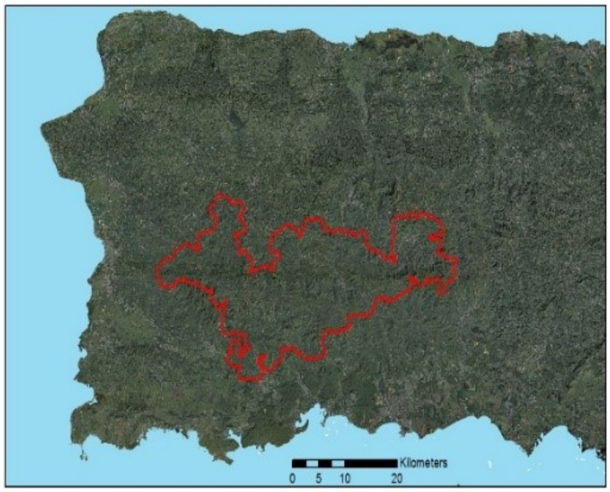


Figure 5: DRNA Target Area (CCP, 2015)

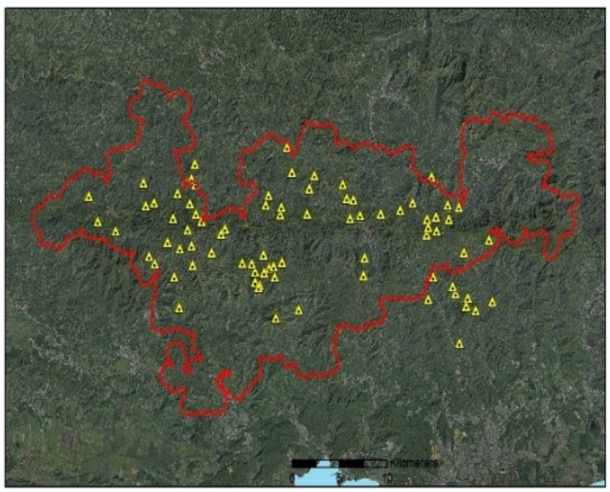


Figure 6: Target Area and Survey Sites (CCP, 2015)

a bachelor's degree or higher, another third had high-school degrees, and the remaining third had below middle school attainment. Most farmers were land owners (82%) and although there was reasonable variance in length of ownership, the majority had substantial experience with coffee growing activities with more than two thirds of the sample having grown coffee for more than 20 years.

The average farm size was 65 acres, slightly larger than the island's typical commercial coffee farm, which is around 25 acres. This is likely due to outlier observations as farms in the survey varied between 2 and 750 acres. On average, 51% of total farmland was planted with coffee, the remaining land was forested land or was used for other purposes. Most farmers planted a variety of other crops with their coffee trees. About 12% of respondents reported using all their farmland for coffee farming, but of those that planted other crops, the majority kept their produce for personal consumption. Commonly cultivated produce included oranges, bananas, plantains, root plants, breadfruit, squash, pigeon peas, papayas, and avocados.

Farmers in the sample were primarily producers for commercial purposes.[4] Roughly 74% of respondents sold coffee beans, and of those, 9.5% sold their coffee to gourmet markets. Around 19% of all interviewees had processing equipment, and 7% had equipment for coffee milling. The average price received per pound of coffee cherries of average quality was \$0.52, but it varied according to buyers from \$0.46 to \$0.58.[5] Farm incomes were low in general, below \$30,000 for 82% of the respondents and below \$10,000 for 49% of respondents. Not surprisingly, respondents reported non-farm sources of income had become increasingly important for coffee growers.

According to the survey, over 65% of farmers in the survey reported growing shade coffee in their farms, suggesting there exist economic benefits for farmers from shade coffee cultivation. About 34% respondents were growers of both sun and shade coffee, 28% only produced sun coffee, while the remaining reported producing coffee under shade or semi-shade conditions (22% and 16%, respectively). It is worth mentioning that there are some standards and guidelines to establish whether a coffee plantation is shaded, semi-shaded or not shaded at all. However, these guidelines are not widely known or implemented and there is record of farmers following traditional knowledge and cultural definitions to report their plantations as shade or semi-shade coffee farms. Thus, it is not clear that all of the reported shade or semi-shade farms are necessarily good environments for maintaining

[4]In PR, virtually all farmers are commercial farmers as there are strong incentives for farmers to obtain most of their annual income from farm-related activities. Under the *Agricultor Bonafide* law, farmers that derive over 50% of their annual income from farming are exempt from any taxes.

[5]Since 2013, 85% of Puerto Ricos coffee brands are owned by, the Puerto Rico Coffee Roasters company, a branch of Coca-Cola.

biodiversity or improving soil quality. This is often called the “shades of shade”paradox.

About 82% of the respondents were participants in some assistance program, almost all of them participated in programs ran by the Department of Agriculture favoring sun coffee cultivation. Of the 81% of farmers receiving DA’s assistance, 53.6% benefited from the wage subsidy program. Around 39% of the surveyed farmers participated in in federal programs promoting shade coffee cultivation, almost all of them were also beneficiaries of the DA’s programs (96.7% of them). Overall, 32% of farmers receive both kinds of assistance. Table 3 provides a summary of the profile of participant and non-participant farmers surveyed by CCP in 2015.

As shown by table 3, there is a apparent contradiction between farmers’ choice of cultivation practice and the programs they participate in. For instance, of the farmers participating in DA’s pro-sun programs, almost 14% reported only growing shade coffee, while over 20% of farmers receiving only federal pro-shade assistance reported growing only sun coffee.

Other interesting differences from a casual inspection are gaps in land holdings and reported annual farm income. Overall, farmers receiving assitance for both kinds of practices reported higher incomes on average and had larger farms.(Participants of FWS tend to be much wealthier on average, although this sample is also much smaller and the result could be driven by outliers.)

The consistent average percentage of the land devoted to coffee is around 35%. Although among FWS beneficiaries, the percentage is much higher (83%). This may be reflecting larger land requirements for sustaining the shade tress within the coffee plantation. According to the surveys, almost no farmer grows crops for commercial purposes in the remaining area. In general, a preliminary inspection of the sample suggests it is reasonable to suspect that participation in alternative programs, the decision to grow shade coffee, and farmer wealth (income and land) to be correlated factors.

Ideally, for the empirical analysis the data described above would be complemented

Table 3: Characteristics of Farmers in the CCP Survey by Participation Status

	Full Sample	Any Program	FWS	NRCS	PRDA	FWS/NRCS +PRDA	PRDA wage
Percentage of farmers involved		82	5.60	33.7	80.9	32.6	43.80
Percentage growing sun coffee only	34.80	35.60	20	21.40	36.10	24.1	38.50
Percentage growing shade coffee only	32.6	15.1	0	25	13.9	20.7	15.4
Percentage growing semi-shade coffee	16.9	13.7	40	17.9	13.9	17.2	12.8
Percentage growing sun and shade coffee	15.7	35.6	40	35.7	36.1	37.9	33.3
Av. land size (in cuerdas)*	67.14	72	91.6	116.42	71.77	120.5	90.13
Av. area in coffee cultivation	33.5%	34.3%	83%	34.1%	35.4%	39.5%	40.4%
Av. annual farm income ($)	16,000	18,300	60,000	28,000	18,600	30,345	30,100
* 1 cuerda = 0.9 acres							

with historical agricultural data from the USDA census and historical records of program participants and benefit receipts made available by the US FWS, NRCS and PRDA. Unfortunately, at the moment such data is unavailable. Public data from the US Census in digital format for Puerto Rico is difficult to find; there are no spreadsheets available containing PR Agricultural Census Historic data; and permission is needed from agency officials to access the US FWS and NRCS data. In addition, given that coffee is grown commercially only Hawaii and Puerto Rico, there are concerns that USDA Census data for this commodity may not be particularly reliable.

An advantage of working with independent survey data from a randomly selected sample is that it circumvents dealing with potential selection bias and measurement error issues that would arise when using only Federal US government data.[6] However, despite this advantage, this paper suffers from data issues inherent to the rather intransparent policy context in Puerto Rico. In Puerto Rico, there seems to be a general lack of

[6]Recall that under the *Agricultor Bonafide* law, farmers that derive over 50% of their annual income from farming are exempt from any taxes. Therefore, there are strong incentives for farmers to under-report their incomes and production capacities of their farms.

coordination between state and federal agencies. Furthermore, there appear to be other incentive programs in place but their definition and function is rather unclear to farmers and researchers. An imperative threat to the validity of the findings resulting from the any investigation of agricultural policy in Puerto Rico involves the confounding effects of these uncertain programs.

4 Theoretical Model and Empirical Methods

The Puerto Rican coffee farmer problem can be modeled as an adoption problem in presence of environmental externalities. In this model, coffee farmers choose whether or not to adopt conservation management practices or to abandon their plantation altogether based on expected market performance and government subsidies when available.

In this model, a farmer adopts shade management practices if he considers this to be a more profitable practice over time. In addition to predicting farmer behavior, this theoretical framework allows for the explicit characterization of the decision-making process, facilitating researchers to address questions of policy efficiency. With this simple model, the optimal level of PES can inferred (i.e., the level of payments that nudges farmers to grow the amount of shade coffee leading to the socially efficient provision of ecosystem services).

Below the adoption of shade-management regime decision is presented as a multiple stage problem where adoption occurs at the first stage. Here, a farmer that uptakes the shade-plantation strategy forgoes 5 years of coffee revenues and once the plantation starts producing at full capacity, yields are lower than yields from an analogous sun coffee farm. However, the adopting farmer will receive a stream of profits that outlasts those of the sun plantation by up to $T + 5$ periods, where T is the lifespan of a sun plantation.

Take F to represent fixed costs of transitioning from sun to shade cultivation, π_{sh} to be the annual profits from a shade farm, t the time index, and δ the discount factor.

Then, the expected, discounted, stream of profits from transitioning to a shade farm is:

$$E_0 \sum_{t=0}^{2T+5} \delta^t \pi_{sh} = -F + 0 + 0 + 0 + 0 + E[\delta^6 \pi_{sh} + \delta^7 \pi_{sh} + ... + \delta^{2T+5} \pi_{sh}] \tag{1}$$

And the stream of profits from a sun farm, π_{su}, is:

$$E_0 \sum_{t=0}^{T} \delta^t \pi_{su} = \pi_{su} + E[\delta \pi_{su} + \delta^2 \pi_{su} + ... + \delta^2 \pi_{su}] \tag{2}$$

A farmer will adopt the shade regime if (1) is larger than (2). In this case, the positive externality of the shade plantation is realized. On the contrary, if (2) is greater than (1) a farmer will cultivate sun coffee and it is under this scenario where it is relevant to address the question of what value of external benefits justifies different levels of subsidies nudging farmers to grow the less profitable variety of coffee.

The presence of positive externalities from adoption of shade-coffee management practices, explicitly, increased regional agricultural wealth via spill-over effects onto the productivity of other farms, and the intrinsic value of biodiversity, calls for a social planner to implement a solution so that the optimal number of farmers prefers shade over sun.

The social planner faces the task of finding the optimal number of farmers that uptake conservation management practices to maximize social welfare. That is, in his optimization problem, the social planner takes into account all private benefits from coffee farming, (1) and (2), as well as the external benefits that arise from shade coffee management practices. Given a market instrument, his task becomes finding the optimal level of subsidy that will bring (1) to equal (2) plus an additional benefit that is enough for the optimal number of farmers to prefer shade over sun coffee.

Taking parameters from the literature documenting yields of sun and shade coffee plantations in Mexico, the yield differential between sun and yield coffee is assumed to be 30% and this yield differential is assumed to directly translate into a profits differential of 30%. Further assuming a discount factor of 0.99, and a lifespan of 15 years for coffee trees grown under a sun regime ($T = 15$), then equations (1) and (2) are equal when:

$$
\begin{aligned}
-F + E_0 \sum_{t=6}^{2T+5} \delta^t \pi_{sh} &= E_0 \sum_{t=0}^{T} \delta^t \pi_{su} \\
-F + 0.7 \cdot E_0 \sum_{t=6}^{35} 0.99^t \pi_{su} &= E_0 \sum_{t=0}^{15} 0.99^t \pi_{su} \\
0.7 \cdot [E_0 \sum_{t=6}^{15} 0.99^t \pi_{su} + E_0 \sum_{t=16}^{35} 0.99^t \pi_{su}] &= E_0 \sum_{t=0}^{5} 0.99^t \pi_{su} + E_0 \sum_{t=6}^{15} 0.99^t \pi_{su} + F \\
0.7 \cdot E_0 \sum_{t=16}^{35} 0.99^t &= E_0 \sum_{t=0}^{5} 0.99^t + 0.3 \cdot E_0 \sum_{t=6}^{15} 0.99^t + \frac{F}{\pi_{su}} \\
10.85 &= 5.85 + 2.7 + \frac{F}{\pi_{su}} \\
2.3 \cdot \pi_{su} &= F
\end{aligned}
\tag{3}
$$

According to equation (3), a farmer will be indifferent between growing shade and sun coffee if costs the farmer bears for transitioning into shade coffee is 2.3 times as large as the annual profits from growing sun. Thus, a subsidy program looking to achieve this end would provide the farmer with lump sum payments with the present value of $2.3{\cdot}\pi_{su}$.

According to the 2012 USDA Census for Puerto Rico (table 12), the average market value of coffee sold per farm was \$6,537 in 2012 and \$7,366 in 2007. The Census also reports per farm costs of production for all agricultural commodities[7]. These expenses include tress purchased, commercial fertilizer, gasoline and fuel, wages and salaries, contract labor, machine hire, agricultural chemicals, among other. Aggregating wages, salaries and contract labor expenses, yields an estimated per farm cost of \$24,509 in 2012 and \$19,135 in 2007. These estimates imply negative profits, but these estimates aggregate costs to all farms not just coffee farms, and they may not account for wage-subsidies that farmers receive from the department of agriculture. Without more information it is perhaps irresponsible to offer an approximation of annual profit for coffee sales per farm, but it

[7] This data is found in the 2012 Census' table number 11

may be very low given the large difference between expenses and revenues. In this case, F would not have to be very low for it to be economically profitable for a farmer to chose shade over sun coffee.

Nevertheless, it is important to remember that the result from equation (3) is highly restricted and ignores dynamics in choices of production technologies and input mixes. There are substitutabilities between labor and capital inputs that may call for a different input mix in a shade coffee farm than in a sun coffee plantation. For instance, shade plantations require more labor than sun plantations, partly for maintenance of the canopy. The fact that Puerto Rico is a US territory means that it is covered by US federal minimum wage laws, this condition makes choosing a labor-intensive activity, like shade coffee production, uncompetitive relative to neighboring Caribbean nations and therefore unattractive as a business.

If it were possible to parameterize and solve explicitly a farmer's profit maximization problem, it would also be possible to compare the stream of profits a Puerto Rican farmer expects to attain by growing shade or sun coffee. In turn, the optimal level of subsidy for ecosystem services (improved soil fertility, increased habitat for wildlife, and decreased erosion) would correspond to the amount that would make a farmer indifferent between these two streams.

Looking ahead towards future research, it seems key to find the elasticity of substitution between labor and the capital input in the production of sun or shade coffee. If the reduction in capital input costs outweighs the increase in labor input costs that would be necessary to keep production of shade coffee on par with yields from a non-shaded plantation, and if the subsidy allows a farmer to cover the upfront fixed costs of planting the shade canopy and forgone profits of the first years of production (while the coffee trees grow), then a Puerto Rican coffee farmer should find it lucrative to switch into a shade management regime.

On the other hand, if increases in labor requirement translate into substantial increases in cost, a farmer would only choose to grow shade coffee if the subsidy not only covered the upfront cost and forgone profits of the first 5 years, but also the annual economic losses for the following 30 years (if the average T was 15 years).

In addition, it seems important for conservation agencies to explore the role of risk preferences on production decisions. For instance, observational evidence suggests that farmers prefer to sell their produce to a large retailer (like PR Coffee Roasters) as average quality for lower prices, in exchange for the certainty that their produce will be bought. High-quality coffee traders tend to have difficulties meeting a minimum volume of high quality beans for them to enter the gourmet coffee market and remain profitable. A retailer of high quality beans that cannot meet the volume may be forced to mix high quality with average quality beans to remain profitable. This practice results in the retailer not being able to charge the specialty coffee price as his mix is now downgraded.

Ultimately, this impacts the coffee producer as he will not be offered a premium for his high quality beans since they will end up in the mix with average quality beans and sell for average quality prices to consumers. This farmer will not choose to grow shade coffee as he cannot capitalize on the qualities of the product. For agencies pushing the shade coffee agenda, investigating the option of encouraging farmers to form cooperatives that can meet the minimum volume required by the retailer may be an attractive option. If farmers can guarantee to meet the minimum volume, then they can be certain to receive a higher price for their beans, therefore finding an economic incentive to convert their farms to shade coffee plantations.

Along the line of exploring the role risk preferences on production decisions, another consideration that may be important is the accounting of potential income effects on risk preferences. Apparently, Puerto Rican coffee farmers are increasingly willing and able to become small producers and processors of specialty or gourmet coffee (Alamo et al., 2006). This trend may be explained in part by changes in consumer preferences for coffee, by changes in relative prices between specialty and traditional brews of coffee, and the availability of new processing technologies at affordable prices. Said shift in livelihood orientation may impact attitudes towards risk and risky farming practices (such as growing shade coffee). If the impact is found to be positive, then the level of subsidy necessary to incentivize farmers to grow shade coffee may actually be lower than anticipated. The opposite is true if non-farm wages are associated with tighter liquidity constraints and higher risk aversion among coffee farmers.

4.1 Empirical Methods

A farmer's decision to participate in FWS and NRCS conservation programs and his choice of land management practices (e.g. the use of a shade canopy) are likely interrelated and determined simultaneously. Farmer may choose to convert their plantations to shaded farms in order to receive benefits form conservation programs. However, it is also possible that farmers that already grow some shade coffee in their lands are the ones applying to receive program benefits.

The reality described above illustrates a complex system tainted with selection bias that is difficult to model and track. In this exploratory empirical analysis, I abstract away from much of the particular intricacies in the system to evaluate the impact of participation conservation programs on land management practices following the three-stage framework presented in Wissen and Golob (1990). I estimate a rudimentary system of two simultaneous equations involving binary endogenous variables. I employ a bivariate probit estimation procedure and instrumental variables to correct for endogeneity.

The three-stage procedure is the following. In a first stage, the structural equation is expressed in terms of exogenous variables and random disturbances. The reduced model is estimated to retrieve the predicted parameters via Maximum Likelihood Estimation. In the second stage, the structural equation is estimated by replacing the endogenous right-hand side variables with the continuous fitted latent instruments constructed in the first stage. This methodology yields consistent and unbiased estimates. However, given the use of instruments in the second stage, the reported standard errors are not accurate. Hence, the final stage of the procedure involves correcting the variance-covariance matrix of estimated disturbances to compute the adequate standard errors.

The structural econometric representation of the joint decision model is defined as:

$$P_{ij}^* = \theta_1 Shade_i^* + \alpha_0 + \alpha_1 X_i + \alpha_2 Y_i + \alpha_3 Z_i + \alpha_5 p_i^c + \sum_{k \neq j} \alpha_k P_{ik} + \epsilon_{1i} \tag{4}$$

$$Shade_i^* = \theta_2 P_{ij}^* + \beta_0 + \beta_1 X_i + \beta_2 Y_i + \beta_3 Z_i + \beta_5 p_i^c + \sum_{k \neq j} \beta_k P_{ik} + \epsilon_{2i} \tag{5}$$

The dependent latent variables are P_i^* and $Shade_i^*$. P_i^* is a binary measure of participation decision by farmer i in program j that takes on the value of 1 if the farmer is a current participant in the j^{th} incentive program available to Puerto Rican farmers. In total, there are over 30 such programs, thus, for analytic convenience I bundle them by providing agency. In total there are 3 types of programs, (1) FWS programs, (2) NRCS programs and (3) programs offered by the PR Department of Agriculture (PRDA). The former two offer shade incentives, while the latter offers incentives to grow sun coffee. In turn, $Shade_i^*$ signals whether farmer i uses a shaded canopy in his coffee plantation.

Vectors X_i, Y_i, and Z_i consist of exogenous variables and include farmer-specific attributes, farm-specific variables, and managerial characteristics, respectively. The variables included in vector X_i are age, gender, and indicator variables for different levels of educational attainment. Vector Y_i includes variables that characterize the production capacity of the farm. These include total land owned, area under coffee cultivation, farm income, whether the farm sells its produce by bulk (this is measured by an indicator variable that equals 1 if the farmer reports selling his product by the quintal, or by 100 lbs.), and whether the farmers sells his product in specialty markets.

Vector Z_i includes variables that define farmers' managerial aptitudes and attitudes. Variables included here are ownership status, number of years that farmer i has managed the farm, whether the farmer grows only coffee, whether the farmer inter-crops, whether the farmer leaves land undeveloped for forest, the farmer's current management practice (sun, shade, part sun and part shade, or semi-shade), whether the farmer has changed from sun to shade or vice versa, and whether the farmers is also involved in any of the coffee processing stages.

Variable p_i^c represents the price per pound of coffee received by farmer i.[8] Variables P_{ik} are binary variables taking the value of 1 if farmer i participates in any of the alternative incentive programs available to him where $k \neq j$. Lastly, ϵ_1 and ϵ_2 are the error terms. Summary statistics of the variables included in the econometric estimation are presented in Table 4.

5 Results

Results from the simultaneous bivariate probit estimation procedure described earlier are reported in Tables 5 and 6. Table 5 shows the results of various regression on the unrestricted sample of farmers. The first four columns in Table 5 show the results of the bivariate simultaneous probit regression when participation in any program (pro-sun or pro-shade) is considered. Columns 5-8 show the results corresponding the analysis when only participation in conservation programs (offered by the FWS or the NRCS) is considered. Finally, the last four columns show the similar results when only participation in the DA's pro-sun incentive programs is analyzed. Table 6 shows the transformed coefficients to reflect estimated marginal effects for variables that were significant in the regressions summarized in Table 5.

Looking across the results under different participation scenarios, it is possible to detect that farmers are more likely to grow shade coffee if they are participants in pro-sun

[8] In Puerto Rico, the price of coffee that consumers pay is fixed by the Department of consumer affairs (DACO). However, in the data, we do observe variation in the prices received by farmers. The variation seems correlated with scale of sell and processing of the beans done in situ. These correlations are 81% and 70.5%, respectively.

programs offered by the DA, if they are more educated, if they report lower incomes, and if they do not leave forested land uncultivated (which is non-surprising, as this otherwise uncultivated forested land can be defined as a shade–providing canopy).

The most interesting result is that, ironically, receiving assistance for cultivating sun coffee increases the likelihood of growing shade coffee. As shown in columns 2 and 6 of table 6, being a participant in pro-sun programs is the single most important factor determining whether or not farmers grow shade coffee. Farmers that receive DA's assistance are 88% more likely to grow shade coffee than farmers that do not benefit from pro-sun programs. Paradoxically, the participation effect is not significant for participants of conservation programs alone, as shown by column 3 in table 6. Despite the oddity of this findings, it is well supported by the fact that 32% of the interviewed farmers receive both types of subsidies (see Table 2).

The impacts of having a graduate degree and reporting low farm income are also intriguing. According to the results, farmers with graduate degrees are significantly, and substantially more likely to grow shade coffee than farmers with low levels of education. However, they are also less likely to participate in either sun or shade subsidy programs.

Consistently, farm income is negatively related to the likelihood that farmers grow shade coffee, although the effect is small. It is very likely that this sign is obscuring some of the dynamics in management choices. For instance, it is possible that farmers that are not doing very well financially are interested in shifting to shade coffee in order to reap some benefits from selling at premium prices. In turn, it is possible that these farmers report lower incomes precisely because a shade plantation is not as producing as a sun plantation. Whatever the case may be, together with the important impact of higher on shade coffee cultivation, the negative income effect may be reflecting a story of structural changes in non-farm employment in Puerto Rico. For instance, there are anecdotes of absent landowners with larger non-farm incomes that can either afford to switch to shade farming or who are not as sensitive to lower profits from the coffee farm.

A second block of interesting findings are the determinants of program participation. Based on the sample data, very little can be said with confidence about the determinants of farmer participation in a program when the identity of the agency administering the program are disregarded (columns 1-2). Also, many of the significant effects are trivially small. However, there are some worth discussing.

The most striking result is that growing shade actually determines the decision to participate in shade programs, suggesting there may be some evidence of federal agencies crowding out otherwise undistorted private efforts. The positive and significant effect that the amount of uncultivated forest has on shade program participation is supportive of that hypothesis. Although there is no evidence of this in the data, the strong effect that leaving some area of farmland as undeveloped forest has on program participation is also consistent with the speculative suspicion from overseeing agencies that farmers leave areas of land undeveloped to maintain a flexible definition of their farming practices (known as the shades of shade paradox) allowing them apply for benefits from as many programs as possible regardless of possible conflicts between the objectives of these programs.

Market variables are also important factors in the story of program participation and shade coffee cultivation. In general, farmers are more likely to participate in shade-incentive programs if they have access to specialty coffee markets, if they are fetching lower prices, and if they are not involved in the roasting process (i.e. they are not Torrefactores). I suspect that these farmers are not roasting their coffee precisely because they have access to specialty shops–which are likely doing the roasting. Interestingly, “newer”farmers, those who have spent less time managing the farm are also more likely to participate in these programs, although this effect is very small.

In turn, farmers are more likely to participate in sun-programs if they receive higher prices and if they are involved only int he initial stages of coffee processing (they are Beneficiados). The price effect is also likely absorbing some of the dynamics in the participation and management practice decisions, however they could also be hiding institutional details about farmer relationships with the Department of Agriculture. The DA is after all, an important buyer of coffee beans in PR.

Other significant findings include the effect of farm size, land holdings, and productive capacity as indicated by whether or not farmers sell their product by bulk (by 100 lbs vs. 28 lbs). In general, farmers with more land are less likely to participate in incentive programs. However, coffee producers that devote more of their land to farming are more likely to participate in incentive programs.

Perhaps contradicting the previous results, producers that sell by in bulk units (by *quintal*) are found to be less likely to participate in sun-directed incentive programs but more likely to participate in shade–oriented federal programs. After conversations with field scientists, this may or may not be related to scale of production in the farm as observational evidence suggests that farmers tend to use *quintal* or *almud* as the unit of measurement based on cultural traditions rather than farm capacity. It could very well be the case that the choice of measurement units may be confounding the effect of unobserved individual characteristics as it has proven highly sensitive to farmer age and cultural upbringing.

Lastly, as shown in Table 5, indicators of farm capacity (like farm size, number of plots owned, and total land holdings) and involvement in high-level processing of the cherries (if the farmer is a *torrefactor* who grinds his own coffee beans), are not important determinants of either one of the two decisions. In turn, Age and the dummy indicator of intercropping are never significant determinants of either one of the two processes.

Table 4: Variable Definition and Summary Statistics

Variable	Description	Mean	Median	Std. Dev.
Shade Coffee	Binary variable equals 1 if respondent reports practicing shade coffee cultivation	0.1573	0	0.366
SemiShade	Binary variable equals 1 if respondent reports growing semi shade coffee in his farm	0.1685	0	0.376

SunShade	Binary variable equals 1 if respondent reports growing both shade and sun coffee	0.326	0	0.47
Sun	Binary variable equals 1 if respondent reports growing only sun coffee in his farm	0.348	0	0.479
Participation	Binary variable equals 1 if respondent participates in any incentive program	0.82	1	0.386
FWS	Binary variable equals 1 if respondent participates in any FWS pro-shade incentive program	0.05	0	0.231
NRCS	Binary variable equals 1 if respondent participates in any NRCS pro-shade incentive program	0.3146	0	0.4669
PRDA	Binary variable equals 1 if respondent participates in any PRDA pro-sun incentive program	0.809	1	0.395
PRDA_wage	Binary variable equals 1 if respondent participates in PRDAs pro-sun wage-subsidy program	0.4382	0	0.498
Age	Continuous, age of respondent	58.63	60	13.189
Gender	Binary, equals 1 if masculine	0.9438	1	0.231
Basic education	Binary, equals 1 if educational attainment is middle school	0.3034	0	0.462
High school education	Binary, equals 1 if educational attainment is high school	0.2697	0	0.446
College education	Binary, equals 1 if educational attainment is a university degree	0.3146	0	0.4669
Graduate education	Binary, equals 1 if educational attainment is a graduate degree	0.089	0	0.287
Farm size*	Continuous, measures size of farm in cuerdas	67.14	25	109.76
# land holdings	Continuous, number of landholdings managed	1.1691	1	0.548
Total land managed	Continuous, area of landholdings managed by respondent	70.67	27	109.46
Annual farm income	Categorical, 1 if between 10,000-19,999; 2 if between 20,000-29,999; etc.	1.607	0	2.2744
Coffee area	Area of farm devoted to coffee cultivation (cuerdas)	22.53	11	25.728
Sells in large scale+	Binary, equals 1 if farmer reports selling by quintal.	0.1685	0	0.376
Sells in specialty markets	Binary, equals 1 if the farmer sells coffee in specialty markets	0.1236	0	0.33
Price per pound	Average price received per pound of coffee	0.9853	0.5357	1.2144

Ownership status	Binary, equals 1 if owner, 0 if sharecrops	0.82	1	0.386
Years as manager	Continuous, time managing the farm	20.9	20	14.97
Main crop	Categorical, 1=coffee, 2=coffee and plantain or citrus, 3 = not coffee	1.281	1	0.62
Coffee Main	Binary, equals 1 if the main crop of the farm is Coffee			
Intercrop	Binary, equals 1 if farmer practices intercropping	0.8652	1	0.343
Forest land	Binary, equals 1 if farmer leaves uncultivated areas for forest	0.5506	1	0.5
Current management practice	Categorical, 1=sun, 2=shade, 3=part sun, part shade, 4=semi-shade	2.315	2	1.124
Change in management practices	Binary, equals 1 if farmer has switch from sun to shade or vice versa.	0.5843	1	0.49
Caficultor	Binary, equal 1 if farmer only grows coffee	0.7303	1	0.446
Beneficiado	Binary, equal 1 if farmer is involved in initial stage of coffee processing	0.191	0	0.395
Torrefactor	Binary, equals 1 if farmer is involved in all processing stages	0.0674	0	0.252
* 1 cuerda = 0.9 acres				
+ The definition of these units used by the USDA is: 1 quintal=100 lbs., and 1 almud=28 lbs.				

Table 5: Results Simultaneous Bivariate Probit

	Any Incentive program				Conservation Program (FWS or NSRC)				DAs pro-sun Program			
Explanatory Variables	Participation		Shade Coffee		Participation		Shade Coffee		Participation		Shade Coffee	
	Coeff.	Std. error	Coeff.	Std. error	Coeff	Std. error	Coeff.	Std. error	Coeff.	Std. error	Coeff.	Std. error
Shade	2.03	3.15			6.73	3.23 *			0.47	1.52		
Participation			3.619	1.76 *			2.472	1.885			9.956	4.178 *
Intercept	-3.92	6.39	-171.8	16770	11.58	1074.76	-36.99	21240	-3.97	3	-210.4	12020
Age	0.01	0.04	-0.01	0.02	0.03	0.03	-0.03	0.03	0	0.03	-0.02	0.03
High-school	-1.35	1.02	0.96	0.89	-3.17	1.46 *	-0.43	0.75	-1.58	0.77 *	3.53	1.79 *
College	3.24	2.06	-1.19	0.82	1.57	1.15	-1.06	0.81	1.79	1 .	-2.5	1.17 *
Graduate	-3.4	2.6	3.15	1.37 *	-3.72	2.11 .	1.66	1.14	-3.12	1.32 *	7.64	3.14 *
Farm size	0.42	0.2 *	-4.97	447.4	-0.95	51.18	-1.44	400	0.21	0.09 *	-5.88	285.3
Plots owned	3.96	2.52	-100.9	9396	-24.92	1074.8	-28.55	8400	2.44	1 .	-116.6	5977
Land	-0.42	0.21 *	4.99	447.4	0.96	51.18	1.46	400	-0.2	0.09 *	5.9	285.3
Farm income	1.04	0.74	-0.6	0.29 *	0.75	0.3 *	-0.58	0.3 .	0.89	0.33 **	-1.61	0.65 *
Area coffee	0.27	0.21	-0.06	0.03 *	0.07	0.03 *	-0.04	0.03	0.03	0.02	-0.08	0.04 *
Sells specialty	19.59	448.92	-0.44	1.67	5.32	1.98 **	0.33	1.41	18.76	395.05	-3.03	5.25
Sells quintal	-20.39	9.72 *	-39.85	1884	6.9	3.34 *	-26.65	13580	-13.85	5 **	-51.06	1689
Price pound	3.28	2.13	3.63	2.48	-2.12	1 *	3.86	3.25	1.78	0.83 *	3.99	2.26 .
Ownership	0.71	1.19	-0.34	0.78	7.82	2.83 **	-0.35	0.84	-0.42	0.79	-0.27	0.89
Time	-0.02	0.03	0	0.03	-0.1	0.04 *	0.02	0.03	-0.02	0.02	0.04	0.03
Coffee Main	1.09	1.09	-0.03	0.7	-1.58	0.93 .	-0.49	0.67	0.29	0.72	-0.14	0.83
Intercrops	-7.08	9.57	268.9	25770	2.75	1.9	65.83	27990	-0.22	2	319.1	17330
Forest land	2.54	1.54	-2.25	0.85 **	6.17	2.29 **	-2.39	1.07 *	2.25	0.8 **	-5.41	2.1 *
Change	1.34	1.32			-2.07	1.19 .			1.34	0.75 .		
Beneficiado	10.21	5.93 .	-0.39	3.82	-0.93	1.2	-1.13	5.48	11.09	3.4 **	2.39	3.5
Torrefactor	-22.47	448.92	-6.76	15000	-4.13	2.39 .	-6.94	9585	-20.59	395	-4.7	13240
N	89		89		89		89		89		89	
K	21		20		21		20		21		20	
AIC	71.42		76.71		74.01		80.46		85.24		70.62	
Significance codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1 1												

Table 6: Marginal effects significant variables in Table 5

	Any Program		Conservation Programs		DA pro-sun programs	
Explanatory Variables	Particip. (col-1)	Shade (col-2)	Particip. (col-3)	Shade (col-4)	Particip. (col-5)	Shade (col-6)
Shade			0.63 *			
Participation		0.39 *				0.88 *
High-school			-0.3 *		-0.2 *	0.31 *
College					0.23 .	-0.22 *
Graduate		0.34 *	-0.35 .		-0.4 *	0.68 *
Farm size	0.04 *				0.03 *	
Plots owned					0.31 .	
Land	-0.04 *				-0.03 *	
Farm income		-0.06 *	0.07 *	-0.07 .	0.11 **	-0.14 *
Area coffee		-0.01 *	0.01 *			-0.01 *
Sells specialty			0.5 **			
Sells quintal	-1.75 *		0.65 *		-1.76 **	
Price pound			-0.2 *		0.23 *	
Ownership			0.74 **			
Time			-0.01 *			
Coffee Main			-0.15 .			
Forest land		-0.24 **	0.58 **	-0.29 *	0.29 **	-0.48 *
Change			-0.2 .			
Beneficiado	0.88 .				1.41 **	
Torrefactor			-0.39 .			
Significance codes: 0 *** 0.001 ** 0.01 * 0.05 . 0.1 1						

6 Policy Implications

In Puerto Rico, little research has been done about the status of coffee production, the influence of governmental policies on farming practices and the attitudes of farmers towards sustainable production practices. According to a recent survey, the majority of coffee farmers are recipients of conditional state subsidies promoting the cultivation of sun coffee (81%). However, a large portion of them also report growing some shade coffee in their lands (65%) and some of them also receive subsidies linked to this practice (32%).

The primary objective of this study was to investigate the factors that determine farmer participation in conservation programs and the impact of said programs on adoption of conservation practices. A secondary goal was to explore new linkages between competing policy instruments and conservation agriculture adoption decisions. The empirical results indicate that farmers are about 50% more likely to participate in conservation programs if the sell their product in specialty markets, 58% more likely if they leave land undeveloped for forest growth, and 63% if the already use shade cultivation practices. Other factors were significant but their effect is either small or difficult to disentangle.

On the other hand, variables related to participation in Department of Agriculture's pro-sun incentive programs are indicators of economic performance of the farm. For instance, as farm income increases, farmers are 11% more likely to participate in the DA's programs. Also, farmers that process their coffee cherries are 141% more likely to receive DA's assistance. This contradiction, that wealthier farmers are more likely to participate in assistance programs, may indicate that larger farmers who may be more likely to be vertically integrated farmers may also be more closely related to the DA and therefore more likely to receive DA's economic assistance.

In regards to the decision to adopt shade-management practices, the results suggest it may be farmers that have received higher levels of education and may therefore have access to additional sources of income who can afford to become producers of shade coffee. Finally, what is perhaps the most interesting result from this analysis, is that farmers participating in pro-sun incentive programs are also more likely to adopt shade management practices.

One plausible explanation for this counterintuitive finding is that coffee farmers in Puerto Rico are confused over how the multiple various types of incentives programs available to them are tied to managerial conditions. Another possible explanations is that farmers try to remain eligible to receive benefits from conservation programs as well as sun-oriented programs by keeping both types of cultivation in their farms. This story that farmers are more likely to use conservation practices in order to remain eligible to receive benefits from conservation programs is supported by the strong effect that growing shade has on participation and the impact that leaving undeveloped forests in the land has on both, program participation and probability of growing shade coffee.

Ultimately, the results are not necessarily indicative, but are suggestive, that the case of conservation incentives programs in Puerto Rico is one of good intentions accompanied by poor oversight and a high degree of mis-coordination, all factors that enable a form of rent-seeking among coffee farmers in PR. Based on this study, federal environmental agencies interested in improving the targeting of existing programs should be wary of displacing or even duplicating the efforts from antagonistic state programs that favor a mono-crop-type of coffee cultivation as these seem to be, ironically, the most important driver of the decision to adopt environmentally beneficial management practices.

For the Department of Natural and Environmental Resources of Puerto Rico to meet its expansion of protected habitat area in the island by encouraging farmers to adopt shade coffee management practices, it is possible that simple income-transfer programs that allow farmers to afford switching from sun to shade coffee are perhaps a more efficient way to promote biodiversity conservation practices than the current schemes in place. Alternatively, conservation agencies may consider devoting their resources to new routes that also induce conversion to shade coffee cultivation such as encouraging the creation of shade coffee certification programs and farmer cooperatives, or supporting other means for improving farmer access to gourmet markets, high-end retailers and consumers.

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