Social-Economic Benefits of Payment for Environmental Services in Yaque del Norte Watershed, Dominican Republic

by

Santa Felicita Rosario de De Jesus

Thesis submitted to the faculty of the

Virginia Polytechnic Institute and State University in the

partial fulfillment of the requirements for the degree of

Master of Science

in

Agricultural and Applied Economics

Advisors:
Brad Mills (Chair)
George Norton (Co-chair)
Department of Agricultural and Applied Economics
Carol Franco
Department of Forest Resources and Environmental Conservation

Blacksburg, Virginia U.S.A.
July 31, 2018

Abstract

This research analyzes private and social costs of forest conservation in Yaque del Norte watershed, DR. It calculates private costs as average annual income from farming activities and social costs as the externalities from erosion and CO_2 emissions. Social cost estimates are based on the difference in erosion and CO_2 between conserved forest and other land use categories. The effect of soil erosion on the wellbeing of people is measured by its effect on reduced space at Tavera dam for water availability to generate electricity and to irrigate agricultural lands downstream. The social cost of increased annual carbon emission from potential land use change is estimated using IPCC default emission factors and social cost of carbon estimates. Private costs are inferred from a nonlinear binary response model that estimates the relative importance of factors affecting forest conservation decisions of households. Results show that payment level, measured through rental value, is not significant for landholders' decisions to sign a PES contract. Annual cropland is the most profitable land use in the area. Other important, but less profitable, land covers are pasture, coffee and managed forest. Cropland also generates the highest cost for society in terms of erosion and CO_2 emissions. The comparison of private and social costs shows that only livestock generates a social cost that exceeds average private income. If forest conservation were to be justified based on social benefits, the analysis must include a more comprehensive assessment of what people value from conserved forest in YNW, such as the effect of erosion for water treatment costs. Any proposal to retain forests social benefits, such as REDD+ initiative, should take into account the high cost forgone by forest owners when deciding the distribution of benefits of carbon sequestration.

Keywords: PES, opportunity cost, land use carbon emission, soil erosion.

General audience abstract

Environmental services generate benefits for both private and public entities, which increases the complexity of calculating optimal levels for payment for environmental services (PES). A pilot PES project in the Yaque del Norte watershed of the Dominican Republic is an excellent example of this complexity; with benefits from upland forest conservation accruing to a hydroelectric company, a water supply company, and society at large. Reducing soil erosion through forest conservation can preserve dam capacity for hydro-electric power generation, preserve water quality and lower treatment costs, and reduce the global economic costs of CO_2 emissions. This study evaluates the socio-economic costs of forestland conservation in the Yaque del Norte catchment. The social benefits of carbon stored under forest land are compared to benefits under alternative land uses. In addition, forest land benefits from erosion prevention are estimated using a Universal Soil Loss Equation. Calculated benefits from forestland conservation are then compared to landuse opportunity cost estimates generated through a farm-level survey in the area. Study results show that the opportunity cost of forest conservation in the Yaque del Norte is high; ranging from between RD$10,000 and RD$200,000 per hectare per year. If society values carbon and soil retention as the direct benefits drawn from conserved forest, only lands with low very opportunity costs will be conserved. However, inclusion of the indirect external benefits of forestland conversion suggests that in many cases forest conservation generates greater social benefits than the private benefits associated with alternative land uses from conversion. PES payment levels of RD$5,000/ha/yr that internalize these external social benefits to forest land holders appear to be sufficient to preserve a significant share of current land and generate net social benefits. Further, part of the costs of these PES payments can be borne by hydro-electric and water companies, as they benefit directly from forest land conservation.

Acknowledgements

It is time to say thanks to Jehovah who blesses the plan of diligent (Prob. 21:5) and permitted me to find the perfect institutions that have helped me throughout the process to complete my master program. Thanks to the people who believed on me, here in Virginia Tech, in the Fulbright program, and in the Ministry of Environment and Natural Resources in the Dominican Republic.

Thanks to all my colleagues and friends who mentored me to achieve this dreamed goal**.** Thanks Dr. George Norton for being such a good example of humility and willingness to help others. You are the kind of person that I would like to become. Especial thanks to my primary advisor Dr. Brad Mills for guiding me with such patience during the thesis elaboration process. Thanks to Dr. Carol Franco for listening to me every time I needed.

Thanks to my family and relatives for giving me encouragement and helping me in all required ways. The support of institutions, the example of friend colleagues and the sacrifice of my family have inspired and motivated me to work for my goals. I do not need to mention names; they all know who they are. Thanks to Jehovah for allowing me to meet such good persons of a high human quality.

Table of contents

List of figures

List of tables

List of acronyms

Acronym	**Full name**
AFOLU	Agricultural, Forestry, and Other Land Use
AIRD	Asociación de Industriales de la Republica Dominicana
BAU	Business as usual
BCEF	Biomass conversion and expansion factor for commercial volume
CCAD	Central America Commission of Environment and Development
CODOCAFE	Consejo Dominicano del Cafe
CNE	Energy National Commission
CO_2	Carbon Dioxide
CORASAAN	Aqueduct and Sewerage Corporation of Santiago City
DOM	Dead Organic Matter
DR	Dominican Republic
EF	Emission Factor
EGEHID	Dominican Hydroelectric Generation Company
ER-PIN	Emission Reductions Program Idea Note
ES	Environmental Services
FAO	Food and Agriculture Organization of United Nations
FCPF	Forest Carbon Partnership Facility
GHG	Greenhouse gas
GIZ	International Technical Cooperation of Germany
IPCC	United Nations Intergovernmental Panel for Climate Change
IWG	Interagency Working Group
LDV	Limited Dependent Variable
MAI	Mean Annual Increment
MEA	Millennium Ecosystem Assessment
MEPyD	Ministry of Economy, Planning and Development
MLE	Maximum Likelihood Estimation
MRV	Monitoring, Reporting and Verification
NEP	New Environmental Paradigm
ONE	National Statistical Office
OP	Opportunity cost
PES	Payment for Environmental Services
PSA-CYN	Pago por Servicios Ambientales Cuenca Yaque del Norte
PT	Pie Tablar
REDD+	Reduction of emissions from deforestation and forest degradation
SCC	Social Cost of Carbon
SDR	Sediment Delivery Ratio
SER	Shadow Exchange Rate
SINAP	National System of Protected Areas
SL	Soil loss
UNFCCC	United Nation Framework Convention for Climate Change
USLE	Universal Soil Loss Equation
WTA	Willingness to accept
WTP	Willingness to pay
YNW	Yaque del Norte Watershed

1. INTRODUCTION

1.1. Problem statement

Life on Earth depends on the natural flow of environmental services. Economic growth involves not only the use of scarce products, but also scarce environmental services (ES). The Millennium Ecosystem Assessment (MEA) defines ES as benefits that humanity gets from ecosystem functions. These benefits include, among others, beautiful landscapes, natural filtering of water, habitat for living beings, and carbon storage (as cited in McAfee, 2012). In general, the real value of ES for society is underestimated (Figueroa & Pasten, 2014). The consequences of this undervaluation in resource use choices influence environmental degradation and increasing health problems from pollution.

In developing countries with dense populations, forested watersheds are particularly prone to undervaluation of associated ecosystem services. However, recent initiatives have provided financial compensation (subsidies) to landlords in order to foster their involvement in conservation projects which preserve ES and benefit society (Espinola-Arredondo, 2008). These type of incentives has expanded under the concept of payment for environmental services (PES).

Over the years, public awareness of the role on carbon storage in forest mitigation of climate change and the benefits of forests in mitigating erosion in high rainfall and high slope watersheds has increased along with institutional planning for conservation efforts. Payment for environmental services programs have been implemented in many Latin American countries to achieve improvements in conservation as well as in rural development (Hejnowicz, Raffaelli, Rudd, & White, 2014). The Dominican Republic (DR) started its pioneer project in 2009 with the Payment for Environmental Services in Yaque del Norte watershed (in Spanish PSA-CYN) program. Like other initiatives in Central and South America, the project has the dual objective of conservation and development. The Yaque del Norte river is a strategic asset for agricultural production, drinking water, and hydroelectric generation in the North region and benefit around one third of the Dominican population.

The literature related to PES focuses on program effectiveness in conserving the forest and at the same time raising recipients' income. However, few studies analyze conservation area providers' and demanders' sides simultaneously. The present study provides an estimate of the numerical value of the optimal level of payment to guarantee efficient forest land conservation in this important watershed for the DR. The study assumes that maintaining forest can reduce operational costs for power plant generation and for water supply treatment. In addition, since the DR is actually in the process of approval of a new law to regulate PES nationwide, this research proposes an empirical approach to establishing levels of payment that do not reduce farmers' incomes (private benefits), while increasing social benefits.

How much should be paid to maximize ES, such as reduction of soil erosion and CO_2 emissions, without harming landowner well-being? This study attempts to answer this question for the Yaque del Norte watershed. It estimates the payment level (equilibrium value) that compensates farm households throughout the rural zone of Jarabacoa and Constanza. Benefits of PSA-CYN implementation are currently unknown, but quantitative estimates of two social benefits (sediment yield reduction and carbon sequestration) are presented. The approach and information presented in the study will allow stakeholders to evaluate the feasibility of the PES mechanism as a potential conservation tool in other watersheds with similar land use conflicts.

1.2. Objectives

The global objective of the study is to establish the level of payment for environmental services above Tavera dam that maximizes social benefits in the Yaque del Norte watershed.

Specific objectives for the research are to:

a) estimate the opportunity cost of keeping land as forest,

b) determine the amount and social value of carbon sequestration in conserved forests,

c) estimate the social value of avoided erosion upstream of the Tavera dam, and

d) establish the optimal level of payment for environmental services of forests in the Yaque del Norte watershed.

1.3. Hypothesis

From the beginning, the PSA-CYN project intended to prioritize for conservation areas owned by poor peasants living in rural communities. The large users of water, the Dominican Hydroelectric Generation Company (EGEHID) and the Aqueduct and Sewerage Corporation of Santiago City (CORASAAN), assume that forest conservation, farming techniques and waste disposal from households in the upper areas of basins have impacts on their operation and maintenance costs. They believe that these costs can be reduced by upstream forest conservation, and that landowners must be compensated to keep land as forest and not convert it to more privately profitable, but also more soil eroding, use.

In order to be feasible, the project must have positive effects on the welfare of people in the Yaque del Norte watershed (YNW). Participation in the project occurs on a voluntary basis. Thus the participation decision can be assumed to be made freely as a landholder utility maximizing decision. However, changes to more profitable, but unsustainable land uses in the upper area, can increase maintenance costs of machinery used by the power plant, reduce the average supply and water quality, and increase flash floods.

The specific hypotheses for the research are the following:

a) The social costs associated with forest conversion can be reduced by compensating landholders for the opportunity costs of forest conservation,
b) Program participation will be responsive to PES payment levels,
c) Poorest households have lower opportunity costs and are more likely to participate, and
d) Social benefits outweigh program costs at some level of PES payments.

1.4. Information about Yaque del Norte payment project

The PES project in the Yaque del Norte watershed (YNW) is a pilot designed to assess the viability of using a PES mechanism to generate benefits both for upstream landowners and downstream populations. YNW is known nationwide as an area of ecological and economic importance for the Dominican Republic. The Yaque del Norte river headwaters are in the core of Hispaniola island and travel 298 km to the North passing Santiago city, the second largest city in the country, irrigating the Cibao Valley and ending in the Atlantic at the Manzanillo bay. The Tavera dam is one of the most valuable public investments in the watershed, built in 1972 with the goal to generate electricity, to provide water for human consumption and production.

YNW covers 7,000 km^2, approximately 14 percent of the DR territory. The Tavera dam catchment (780 km^2) was prioritized for implementation of the first PES project. This area has forest cover (conifer and broadleaf forests) over 45 percent of the territory and a mainly rural population of around 82,000 people (Gangotena, 2008). The mountain area is characterized by a combination of steep slopes (32 percent of area with slopes in the range of 7^0-15^0) and small plains; precipitation varies from 1,200 mm to 2,600 mm annually making it one of the wettest zones in the country.

Approximately 30 percent of the area is used for farming and grazing, with a wide variety of agricultural crops grown (Gangotena, 2008). Table 1 shows socioeconomic characteristics of 24 communities with PES contracts and Appendix 1 expands socioeconomic indicators of villages within the study area. The PSA-CYN goal is to contribute to conservation of water sources in YNW through a Payment for Environmental Services program, in order to sustainably enhance water quality and quantity.

The PSA-CYN project began in 2009 as the first national use of economic instruments for conservation of natural resources. Project funders include a hydroelectric company (EGEHID) and a water supply company (CORAASAN), in alliance with the Ministry of Environment and Natural Resources; all of whom are interested in water conservation. The project was justified by the belief that factors affecting water quality, for human consumption and energy generation, are strongly linked to deforestation on steep slopes and to inappropriate waste management especially in communities living in poverty upstream. Thus, project measures focus on forest conservation and reforestation in target micro-watersheds.

Table 1. Summary statistics of socioeconomic variables from villages with PES contracts

Variable	Communities	Mean	Std. Dev.	Min	Max
Number of households (hh)	24	76.5	59.5	18	300
Population	24	291.6	243.6	71	1,228
Average number of persons per hh	24	3.7	0.5	3.1	5.5
Percent hh in low socio-economic status	24	60.7	21.9	21.3	100
Percent 15+ can read and write	24	69.4	13.1	35.8	86.3
Percent households with cultivated land	24	23.8	13.5	0.0	56.8
Percent main occupation agriculture	24	33.5	20.2	4.3	71.4

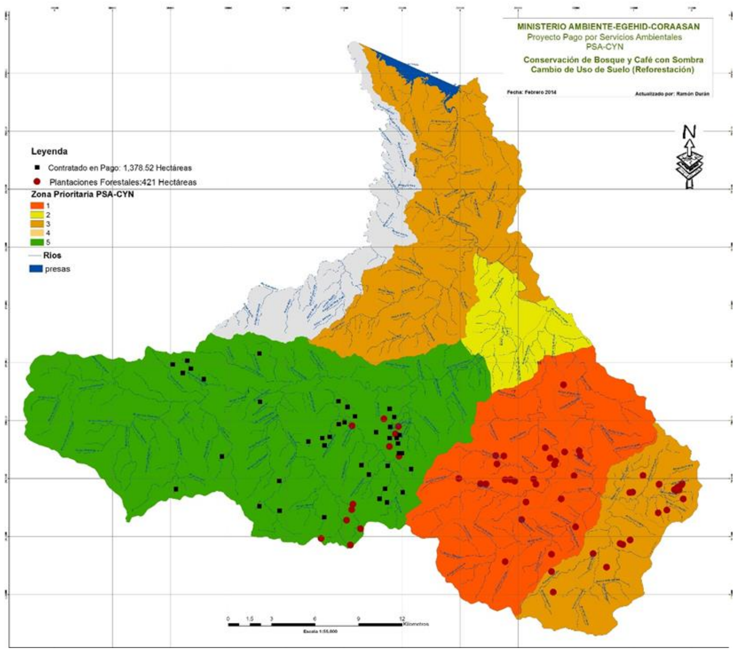
Source: Elaborated from census 2010

The main components of the project are reforestation and payment for forest conservation (Figure 1). As of 2016, around 1,000 hectares (ha) have been reforested. The only requirement for reforestation is the land-owner's willingness to accept the change in land use. From the program side, household eligibility for PES payment is mainly determined by the amount of forest cover on a parcel and the absence of conflict of land tenure. The project has signed 61 contracts for 1,376 ha as of 2016. The design of the PSA-CYN includes criteria to motivate participation of low income households by allowing participation of owners with proof of land possession without title, and by providing owners with smaller plots higher payment per land unit. Also, those who have less than 18 hectares are provided with program technical assistance to prepare required paperwork for participation. The program mainly has enrolled lands that are not being used to generate income from forest products sales.

The program pays landowners to maintain two types of land use: conserved forest and coffee under tree shade. In forest, the average payment is US$50 $ha^{-1}year^{-1}$, while in a coffee agroforestry system the payment is around US$25 $ha^{-1}year^{-1}$. Annual contracts are automatically renewable up to five years. In the reforestation component, no payment *per se* is given to landowners, but there are two direct benefits. The first is wages paid to workers from the communities who do plantation work. Since high unemployment is a great problem, wages paid regularly to agricultural laborers are highly appreciated. The second benefit is to the land proprietor, who can sell the plantation or harvest the trees in the future through a forest management plan. It is expected that payments and reforestation in less productive and highly erosive lands will maintain or recuperate permanent forest cover and, thereby, enhance water conservation.

The initiative has been implemented for eight years and has overcome participants' fears of government expropriation of their lands, which has been a frequent challenge for application of payment mechanisms (see Wunder, 2013). However, it faces criticism that forest protection may reduce local economic growth, and that payments could generate perverse incentives. For example, the payment could finance unwanted productive activities that compete with forest conservation. However, according to Montagnini and Finney (2011) when land use is the core of the payment contract, with no distinction of any specific service, the risk of a perverse incentive is mitigated. In contrast, if only one service, such as carbon sequestration is subject to payment, landholders may be attracted to conserve more carbon-density foreign species and sacrifice native species that might have greater potential to supply other local demanded services or provide greater erosion control (Montagnini & Finney, 2011).

Figure 1. Map of project area



Source: PSA-CYN

Although PSA-CYN is a PES program focused on watershed conservation, there are many expected upstream and downstream impacts. In the high watershed, more resilient land use system, regulation of local temperature, improved water quality, opportunities to increase tourism, direct cash payments, secure land tenure, strengthening of social capital, reductions in unemployment, and keeping soil productivity are listed in the literature as benefits from PES programs. Similarly, downstream and globally, the list of positive externalities of hydrological PES schemes include: reduction of sedimentation (turbidity for drinking water and storage capacity on reservoirs), more stable flux of irrigation water, prevention of flash flooding, biodiversity conservation, and carbon sequestration, among other benefits.

1.4.1. Policy background

Although by legal mandate deforestation in areas with steep slopes and high capacity of water catchment is prohibited in the DR, farmers continue to adopt alternative land uses. Often, the need for food production drives deforestation and forest degradation in settlements in the mountains. The General Law of Environment and Natural Resources in its article 122 bans intensive tillage on soils with slopes greater than 60 percent (Congreso, 2000). This type of restriction, together with declaration of protected areas, historically has exacerbated conflicts with rural households all around the country. Looking for a different approach, the Dominican government is developing legislative initiatives and implementing programs to promote ES provision by private forests. A law proposing payment for environmental services from forests is under study by the Congress (Senado, 2013). However, approval of the PES law needs to be preceded by an understanding of the net economic and social benefits that would result from application. These benefits are hitherto unquantified and the legal initiative is seen as a tax burden by some citizens (AIRD, n/d).

In addition, the country is working with the mechanism to reduce CO_2 emissions from deforestation and forest degradation (REDD+), promoted by the United Nation Framework Convention for Climate Change (UNFCCC) in developing countries. For this purpose, it has received help from international cooperation agencies, such as International Technical Cooperation of Germany (GIZ in German). Since 2010 the DR is supported by the program REDD/CCAD-GIZ[1] to prepare for REDD implementation that would transfer conservation incentive to forest owners.

1REDD program of the Central America Commission of Environment and Development (CCAD in Spanish), System of Central America Integration (SICA in Spanish) and the German Technical Cooperation (GIZ in German).

The DR is a signatory country of the UNFCCC and has submitted its Third National Communication. The document described the state of the country in terms of adaptation and mitigation of climate change, including the DR decision to promote decarbonization of the national economy. The forest covers 39 percent of the nation, but deforestation is still present with an annual rate of 4,000 ha $year^{-1}$ (Tercera Comunicacion National, 2017). In 2016, the Ministry of Environment and Natural Resources launched the project for REDD+ readiness, with the objective to promote sustainable use of forest resources and reduction of emission from deforestation.

The Emission Reductions Program Idea Note (ER-PIN), submitted by the DR to the Carbon Fund throughout the Forest Carbon Partnership Facility (FCPF), proposes the use of Dominican forests to offset CO_2 emissions. This action is rooted in the National Development Strategy 2030 (Congreso, 2012) of which one of the four main axes is a "society with environmentally sustainable production and consumption that adapts to climate change". The Ministry of Environment and Natural Resources, the Ministry of Agriculture, and Ministry of Economy, Planning and Development (MEPyD in Spanish), are in charge of decision-making in this process and ensuring a REDD+ approach in the formulation of public policies (MMARN, 2018). The FCPF of the World Bank is supporting the DR's REDD+ preparation with US$3.8 million (ER-PIN, 2015). As part of this effort, the DR assumed the responsibility to design an Emission Reduction Program Document (ERPD) that defines policies, measures, and actions to be incorporated in planning instruments for sustainable development of the country.

The Yaque del Norte watershed is the pilot area for the REDD+ program. For the DR, the objective is to reduce incentives that drive deforestation and degradation, and to increase incentives for conservation and sustainable use of forest resources that foster economic development of local communities. According to the ER-PIN, DR's lands could sequester 5.4 million tons of CO_2 due to forest conservation and reforestation. Yaque del Norte will serve to validate and adjust the protocols inherent to REDD+ implementation such as monitoring, reporting and verification (MRV), compliance with social and environmental safeguards, resolution of grievances and conflicts, among others. The Yaque del Norte pilot will also define how the country deals with the problem of land tenure uncertainty; a limitation for REDD+ implementation on the ground.

The result of this study will help to move forward not only PES for watershed protection, but also the REDD+ mechanism in the entire country. Implementation on the ground is often a bottleneck of REDD+ initiatives, because a policy designed at the national level often lacks of elements that are only applicable at the local level. Therefore, results and recommendations of this study will be used as inputs for the DR REDD strategy document. And since the DR is a small country, study recommendations can easily be extrapolated and adapted to other watersheds, facilitating implementation of REDD+ projects to prevent deforestation and forest degradation in other regions.

While the DR's legal framework entails [payment for] environmental services, and the country has assumed an international commitment to conserve forest biomass, achieving all those goals in reality requires knowledge of the key variables that influence owners to conserve forests. Also, setting of PES levels requires empirical evidence of the local-watershed-scale social value of forest. Without data or reliable estimates of expected benefits, there will be no support from the political sector, productive private sector, or forest land owners for REDD and other conservation strategies.

2. LITERATURE REVIEW

This chapter reviews concepts and previous research relevant for the study. Payment for ecosystem services, private choices and benefits affecting services provision, cost-efficient payments, social externalities, opportunity costs and benefits of conservation are defined. The chapter ends by summarizing how this study builds on previous work.

2.1. Demand of environmental services and payment

Environmental services represent benefits that humans obtain from nature. In the following, the term environmental or ecosystem services refers to benefits that result from ecosystem processes and functions (Bergstrom & Randall, 2016). Conserving natural ecosystems provides a direct pathway to ensue supply of environmental services such as scenic beauty, cultural values, watershed protection, and atmospheric carbon sequestration. However, the market system often sacrifices conservation for conversion of natural capital to marketable products (Kemkes, Farley, & Koliba, 2010). Since private decisions do not account for social benefits, inefficient allocation of resources occurs.

The goal of a payment for environmental services (PES) mechanism is to fix the inefficient allocation of resources. One broadly accepted definition of PES involves the idea of a voluntary transaction of a service or land use between suppliers and demanders (Wunder, 2013). A PES scheme incentivizes sustainable land cover by securing ecosystem conservation through economic compensation for benefits supplied to society; but it does not necessarily ensure payment for the comprehensive value of services provided by an ecosystem (Montagnini & Finney, 2011). PES programs have spread across developing countries, particularly in Latin America (Hejnowicz et al., 2014), with many schemes focusing on watershed protection (Wunder, 2013) using a variety of approaches. Some projects focus on one service, while others pay for a combination of many services (biodiversity, carbon sequestration, hydrological regulation, and scenic values).

The capacity of PES to secure environmental services depends on the operation rules, specific local conditions, and forces involved in the negotiation process. In theory, PES viability supposes that buyers pay at least the minimum willingness to accept (WTA) amount to sellers of environmental services (Wunder, 2013). Under this condition, for instance, upstream farmers calculate their opportunity cost[2] before freely making the decision on whether to participate in a PES program. With freedom of choice to participate, PES programs should not harm beneficiary households' income. In addition, payment for ecosystem services schemes increase awareness about conservation and environmental quality that benefits the whole society

2.2. Determinants of PES participation

Factors determine PES enrollment both on the demand side and supply side. From the seller (landholder) side, the literature cites opportunity cost, transaction costs, income, remoteness of land, access to information (Le Velly & Dutilly, 2016), as important factors among others. Criteria for payments allocation are established by buyers or regulators, who usually propose PES contracts. Factors that influence contract criteria can include poverty level, land coverage, location, and land tenure. Hejnowicz et al. (2014) analyzed 23 PES schemes and found that PES can produce social benefits for participants, but potential recipients face barriers in accessing information about programs. For instance, farmers associated with community or producer's organizations have higher probabilities of joining PES programs. Trust and empathy with peers may also play a role in this reslt.

2 Value of alternative use of land.

PES enrollment and magnitude of participation is a private choice. Ma, Swinton, Lupi, and Jolejole-Foreman (2012) studied farmers' participation and magnitude of participation in PES programs in Michigan, United States. They found that the most important variables in the decision are the farmer's own benefit perception from ES, farming practices, and information (previous experience with governmental programs and education level). The magnitude of enrollment (how much land enrolled into payment) is mainly determined by the payment offer per unit of land (Ma et al., 2012).

2.3. Cost-effectiveness of PES for environmental services provision

Water-related PES programs with the objective of soil erosion control, can also achieve carbon sequestration through forest conservation and reforestation. The literature on PES mechanisms highlights different approaches to determine private benefits and net social benefits gained as the result of payment programs. Hejnowicz et al. (2014) analyzed socio-economic and environmental results of payment schemes through a capital asset framework[3]. The study conducts a systematic review, and finds that PES programs can generate positive effects on several capital assets, but the effectiveness depends on how programs are designed and managed. The use of PES mechanisms should not be based on blind faith, instead each scheme should be guided by an outcome approach (Hejnowicz et al., 2014). Since capital assets entail factors that affect well-being, this approach can be appropriated to analyze PES schemes that include multiple services.

3 Capital assets refer to aspects that affect well-being of people, such as human and social (food security, poverty alleviation, living standard, social services); natural (forest size, deforestation rate, biodiversity level, environmental services); financial (payment distribution, equity, income); and institutional (governance, institutional development and cooperation, transparency) (Hejnowicz et al., 2014).

Alix-Gracia, De Janvry, and Sadoulet (2008) study how deforestation risk can be used as a decision variable for efficient allocation of funds for optimal provision of environmental services. Using data from a Mexican PES program, they empirically test and compare three payment approaches (flat payments, risk-weighted flexible payments, and benefit-maximizing payments) and find that a benefit-maximizing scheme yields the highest environmental benefits per dollar spent. The benefit per dollar spent ratio was 4:1 in comparison with the actually implemented fixed payment. The mean of payment per hectare at risk of deforestation was estimated at US$86 per hectare (Alix-Gracia et al., 2008). Since a PES's objective is to generate additional units of ES (additonality), accounting for deforestation risk is a valuable criterion, and it is also likely to be positive correlate with low income landownership.

Asymmetric information is one of the challenges faced by many PES programs. Nobody other than landowners and land users know their opportunity costs of conserving forest in more socially desirable ecosystem. Polasky, Lewis, Plantinga, and Nelson (2014) propose an auction as a path to establishing the optimal provision of ecosystem services, taking into account the landowner benefits for developing the land (e.g., farming), and social benefits (spatially dependent) desired by regulators. They demonstrated that auctions provide incentives to landowners to reveal their true opportunity costs, avoiding payments inconsistent with actual costs of conservation. In theory, this method conveys information to the regulator to better calculate a specific payment required for each landowner. However, it is difficult to implement in practice because of the complexity of auction design to achieve the specific outcome.

Ferraro (2007) studied three solutions to the problem of asymmetric information in PES contracts: procurement auction, screening contacts, and land information on characteristics related to opportunity cost. He concludes that the selection of tools to tackle the problem depends on the specific socioeconomic situation (of landholders) and the institutional capacity (of the administrator). The problem is particularly complex in developing countries where land is fragmented among heterogeneous landholders and where public institutions usually lack of resources to operate efficiently.

2.4. Social externalities

An externality is defined as a positive or negative effect on a third party from an economic activity that is not reflected in the price of the good. Most PES mechanisms are based on the assumptions of positive externalities from forest conservation and it is more efficient to promote compensation to farmers that change land use to more environmentally sustainable practices for society than to punish farmers who undertake ecologically destructive land uses (Van Hecken & Bastiaensen, 2010). Farming activities in the higher elevations of watersheds generate negative externalities for water users downstream. PES payment can be conditional on change in land use, movement to more green technologies, or just to keep unchanged a natural ecosystem such as a forest. Approaching environmental degradation from the point of view of externalities, despite its complexity, links together the problem and its solution (Vatn 2005 as cited by Van Hecken & Bastiaensen, 2010). PES should be allocated to forest lands that would not be conserved without the payments.

2.4.1. Additionality

Additionality or incrementality is a pre-condition to justify a PES scheme. Specifically, additional benefits, in the form of positive social externalities or lower negative externalities, are generated because of the payment. A difficulty of PES, relates to the uncertainty as to whether a payment is really necessary to receive additional units of the service. Changes in any outcome variables, such as CO_2, soil retention and others services, must be estimated considering a reference level or baseline scenario without payments.

The concept of additionality is especially relevant to assess the positive externality of forest conservation. If the forest exists without any risk of depletion, for instance, it captures carbon and retains soil then PES payments generate no additional benefits. To justify a PES program, it is necessary to establish a clear risk that the positive externality produced by the forest can be diminished or totally eliminated. For example, in terms of changes in carbon, the baseline called the business as usual (BAU) scenario denotes the amount of human induced emissions and removals that would occur without the project (Ravindranath & Ostwald, 2007). The forest is a source of emissions due to biomass respiration, and it is also a sink that removes or sequesters CO_2 from the atmosphere. Thus, the baseline scenario is the trend in forest land conversion that would happen without PES program intervention, and the reduction of additional tons of CO_2 emissions due to avoided forest conversion are called additonality caused by the PES payment.

2.4.2. Social cost of carbon

The assignment of a social value to the carbon emitted or sequestered is a difficult challenge. The value of a ton of Carbon Dioxide equivalent (tCO_2e) is used as proxy of the environmental degradation cost resulting from CO_2 emissions (Flores, 2016). The two main channels to assign a price on carbon are i) the social cost of carbon (SCC), the price depends on estimated impacts on present and future generations; and ii) the carbon market, the price depends on supply-demand to achieve a cap established by a regulatory framework that allows for trading. The carbon market is currently a mechanism to compensate the potential forgone income due to forest conservation in developing countries.

Putting a social price on carbon emissions intends to internalize the negative effect of CO_2 on ecosystem services, human health, agricultural productivity, infrastructure damage due to rising flood risk, among other impacts of climate change (IWG, 2016). There is no way to have a unique certain value per unit of sequestered carbon because of uncertainties associated with GHG effects and disagreement on the discount rate used to estimate the present value of future wealth. The Intergovernmental Working Group (IWG) of the US Government recently changed the protocol to estimate the present value of social cost of carbon. The new approach implies significant reductions in comparison to 2010 values (see IWG, 2016).

Stern (2007), in the influential review on "The Economics of Climate Change," refers to a wide range of values from less than $0/t$CO_2$ to more than $400/t$CO_2$ (in year 2000 prices). Assuming the UN's current target of stabilization of temperature 2°C above pre-industrial levels which requires GHG emissions below 450 ppm CO_2e, the social cost of carbon is assumed to be around $25/t$CO_2$. This SCC increases if the emissions reduction target is lowered because of the accumulative damaging effect of emissions on the atmosphere (Stern, 2007). SCC estimates often shows a very large range.

2.5. Benefits and costs of forest conservation

2.5.1. Social benefits

Forest generates benefits through soil, water and air, in addition to well-known economic benefits of wood. The benefit of trees for air quality is globally recognized and consequently forest conservation and reforestation are gaining interest. Trees and plants take CO_2 from the atmosphere and store the carbon in their tissues, thus carbon storage can be estimated as a proportion of forest-plant biomass. Due to the larger mass and longer life of trees, carbon sequestered by natural forest and plantations can be significantly greater than what can be fixed by short cycle agricultural crops (Kongsager, Napier, & Mertz, 2012). Rapid biomass growth in the tropic results in higher carbon sequestration rate than is found in other regions on Earth.

Carbon sequestration can be a measure as one component of a positive externality of forest conservation projects. Two measurements of carbon are relevant in relation with forest. One is the carbon stock in the forest at a specific time (usually given in C mass per area), and another is the potential carbon sequestration rate (given in C mass per area-year^{-1}); both can be converted to monetary values (Stoffberg, Rooyen, Linde, & Grounebeld, 2010). Chacón, Leblanc, and Russo (2007) found a rate of carbon fixation of 3.1Mg ha^{-1} per year in a secondary tropical forest in the Atlantic region of Costa Rica.

The value of CO_2 emissions and erosion avoided represents part of the social benefits of conserving the forest. Expansion and protection of forest cover results in an increase in carbon stock in soils and in biomass (Ravindranath & Ostwald, 2007) or at least, it helps to halt deforestation and subsequent ecosystem degradation and reductions in carbon stocks.

Similarly, forest cover can play a positive role controlling soil erosion. Soil particles removed from the surface travel downslope, usually moved by water, but the amount of soil loss depends on the speed of transport process (Kinnell, 2010), which is related with protection of vegetation cover and quantity of runoff (Boardman, 2006). This fact generates an opportunity to deal with erosion because changes in land use can reduce sediment flows. Land use changes can, therefore, significantly alter rates of soil erosion. The effects of erosion and sedimentation are summarized by the Food and Agriculture Organization, FAO (2008) in the following:

> “Sediment can reduce reservoir capacity; impair water for drinking and domestic or industrial uses; obstruct navigation channels; raise river beds, which reduces the capacity

to handle water safely; adversely alter aquatic habitat in streams; fill the spawning grounds of fish; wear down turbine blades in power installations; and cause landslides, which damage people and their structures and block channels, resulting in floods".

Probably the most detailed economic study ever completed in the DR (pertaining to solutions to externalities associated with agriculture) was completed by Blas Santos (1992). Santos studied the soil erosion problem in the Sierra zone of the Dominican Republic accounting for impacts on upstream farmers and downstream consequences on water for irrigation and hydroelectric production. He found potentially high benefits from soil erosion control, but that reforestation of steep slope pastures needs subsidies in order to be profitable for farmers. Further, downstream residents can be better-off by paying subsidies due to upstream producers to reduce the downstream consequences of soil erosion.

2.5.2. Private costs: opportunity cost of forest conservation

Private landholders have multiple choices of land uses, but they often obtain lower benefits from ecosystem conservation or socially desired (optimal) use of lands (Kemkes et al., 2010). In other words, the social benefits of forest conservation can be higher than the private benefits. This difference, between social and private benefits in monetary value, is at the core of the transaction in a PES scheme. The net benefit of a PES scheme depends on the design, the payment level (Alix-Gracia et al., 2008), and the value of the positive externalities produced. Therefore, a PES program should derive the quantity of environmental services and price that balance social demand and private supply of services.

Opportunity costs play a key role as they determine the private supply of land. Naidoo and Adamowicz (2006) modeled opportunity costs for landholders for conserving forest in Paraguay using information of net annual agricultural benefits and spatial changes in agricultural border. They estimate economic benefits for a range of discount rates (5 to 40 percent) with secondary data on prices and production costs for cattle ranching, small crops, and soybean farming. Assuming a scenario where the social planner wants to buy the lands, they estimate opportunity costs from US$33 ha^{-1} to US$927 ha^{-1} (Naidoo & Adamowicz, 2006). If a planner is not interested in obtaining perpetual ownership of the land, the opportunity costs must be estimated for a limited time span.

Borrego and Skutsch (2014) estimated opportunity costs of tropical dry forest in Mexico within heterogeneous parcel sizes. They calculated the net annual rent from a sample of 112 shifting cultivation farmers, using land use activities, market prices of inputs and outputs, and biophysical characteristics of lands. Findings show that for 2011 the mean of annual rent in those lands was on average US$340 ha^{-1} (Borrego & Skutsch, 2014). It is important to note that the distribution of the opportunity costs, even using the same variables in different locations, depends heavily on site-specific conditions.

Ickowitz, Sills, and de Sassi (2017) compare opportunity costs of carbon projects using a dataset of 4,117 households from six tropical countries, including Brazil and Peru in Latin America. They first estimated the carbon stock using the pan-tropical carbon map proposed by Avitabile et al. (2016). They calculated the present value of the opportunity cost per ton of carbon in the forest at US$29.76 with a time horizon of 30 years and discount rate of 9 percent. They also demonstrated that opportunity costs are consistently lower for poor households, which is consistent with Borrego and Skutsch (2014)’s findings in Mexico.

2.6. Summary

Each unit of land has its own characteristics that influence productivity and opportunity costs of alternative land uses. Empirical evidence shows that poorer households face lower opportunity costs for forest conservation (Borrego & Skutsch, 2014; Ickowitz et al., 2017). There are heterogeneous values associated with the opportunity cost of forest conservation in the watershed. Landholders also face distinct economic situations that drive land use decisions. For example, they may develop land for farming or forest production according to land characteristics. A fixed payment may be higher or lower than the willingness-to-accept for landholders (Alix-Gracia, De Janvry, Sadoulet, & Torres, 2005; Peterson, Smith, Leatherman, Hendricks, & Fox, 2014).

The negotiation process of PES contracts is characterized by asymmetric information. The opportunity cost of keeping forest, and consequently its environmental services, is a function of owner (skills, knowledge and preferences) and land characteristics, usually known only to the landowner (Polasky et al., 2014). Changes in land use affect the ecosystem's provision of social benefits. Forests often are beneficial for rural communities due to their interconnection with food security and livelihoods, and by preventing soil productivity loss (see Santos 1992). But, forests can serve beneficial roles outside of the host community. In locations with steep slope and intense rainfalls, forests help to reduce soil erosion, and store significant amount of carbon. This positive effect of forests can be measured as social benefits.

In the case of the Dominican Republic, historically conservation has been imposed through protected areas, which usually conflicts with farmers' economic interests. A PES program, piloted in the Yaque del Norte watershed, attempts to align private and social benefits from forest conservation. Making program adoption voluntary ensures private benefits for participants. However, there is a need to understand participation decisions, particularly the opportunity costs of forest conservation in the study area. The information generated will serve to inform conservation policy decisions, which is the ultimate goal of this research.

3. CONCEPTUAL FRAMEWORK

This chapter first describes the economic framework employed in the study and the rational for PES in a watershed using a principal-agent framework. Factors relevant for the economic analysis are also identified in the section.

3.1. Principal agent theory

The role of the principal is to maximize social welfare, in our case upstream and downstream residents. Analyzing forest conservation with the objective of maximizing the economic benefits implies that conservation takes place up to the point where the additional benefits of further conservation (CO_2 emissions and erosion reductions) are just balanced by the additional costs. This is the familiar necessary condition for maximization problems.

However, the optimal level of conservation that conveys environmental services (ES) is unknown for two reasons: (i) imperfect information among economic actors and (ii) uncertainty about the magnitude of social benefits. We formally state the problem with a principal-agent model. The principal is the economic actor that designs the contract; the other party (agent), usually with more information, decides whether or not to take the contract (Snyder & Nicholson, 2012). The challenge is to find a solution of the model that combines benefits that society receives from forest ecosystem with associated private costs of providing these services.

3.1.1. Principal problem

The social planner (SP) is the principal and wants to ensure provision of the highest value of social benefits net of costs, but the SP does not have complete information to choose forest parcels that satisfy this goal. With symmetric information, the principal, on behalf of the society, could establish a specific payment for each type of agent. The principal is, however less informed than the agent and is, unable to propose an optimal contract for each agent. The SP cannot observe all agents' actions or their characteristics; therefore he is more concerned with the measurable outcome, hectares of conserved forestland after a certain observable period and the associated value of social benefits.

Principal behavior

The SP desires optimal social benefits generated by conserved forest (environmental services). If the benefits generated by forest conservation are large, the principal's optimal PES payment level will be higher. For example, high cost for treatment of turbidity in drinking water and high value of erosion reduction by forest land implies greater social benefit from conservation. However, program participation is positively correlated with PES amounts. Lower PES payments lead to lower participation in the payment program, which in turn reduces the quantity of land in conservation and decreases associated social benefit levels.

3.1.2. Agent problem

A landholder (agent) has private information about his costs and benefits for developing land before signing the contract proposed by the principal. This fact gives the agent an advantage in negotiations. A contract that fairly compensates low cost agent types would imply disutility for high cost agent types, who would not take such a contract. In theory, no agent will accept payments below the level of income they get from the land without a payment contract (their opportunity cost). Agents know the payment level needed to retain lands in forest, but the principal does not know the agents opportunity cost.

Agent behavior

Based on an agent's attributes and the characteristics of the land, an owner can either decide to keep land in forest with a certain level of compensation or to develop it with a profitable activity.

Assuming that landholders hold the right to develop their lands and maximize profits, they must be compensated to conserve the land as forest if the land has higher opportunity costs.

3.2. (Microeconomic) Conceptual model

The social benefit of conserved forest can be given in terms of social cost of carbon (a) and cost of erosion (b) per hectare of land (q). A simplified presentation of social benefits (B_p) is given by:

(1) $$B_p(q) = a(q) + b(q)$$

For maximizing benefits, we can write the optimization model as:

(2) $$\max_{q_i} \sum B_P(q_i) - PES(q_i)$$

Subject to $$\text{Max } U[y(q_i)]$$ $$y = \max\,[PES(q_i), FL(q_i), OP(q_i)]$$

where $B_P(q_i)$ represents benefits of CO_2 and soil retention of agent *i* *(i=1,2…n)*. Opportunity cost, $OP(q_i)$ is the potential income for developing the preferred alternative in a hectare of land for farmer *i*. $PES(q_i)$ represents the amount of money from PES payments and the contract-allowed forest benefit stream and FL(qi) are existing benefits stream of retained forest land. The problem is solved by finding the quantity of land (q) that maximizes the equation.

With complete information, the SP can pay everyone the higher of $OP(q_i)$ or FL(qi) until $PES(q_i) = B(q_i)$ for the last program participant. With incomplete information, the principal only can pay a flat PES, where the marginal benefit of a quantity of forestland is the same as the payment ($B_P'(q)$=PES). If the PES were higher than the marginal benefit, the social gain from one extra hectare of conservation would be less than the cost. Similarly, if the PES payment is lower than the marginal benefit, the social gain from one additional unit of conservation would be greater than the cost; therefore it would be better to increase participation by increasing the payment level. The principal needs to know how agents responsiveness to PES payment drives participation decisions through the functions PES(q) and OP(q).

The SP also needs to know $B_p(q)$ based on the value to society for water treatment, cost of soil erosion for hydroelectrical generation, CO_2 and other greenhouse gas (GHG) emissions from forest land loss. The agent's behavior delineates the marginal population reachable with increasing PES payments.

A landowner's benefit from conserving the forest depends basically on the difference between his opportunity cost and the PES payment. The opportunity cost (OP_i), potential income for developing a hectare of land *i*, depends on the biophysical characteristics of the land (x_i) and socioeconomic features of the landholder's household (y_i). The response of landholders can also be correlated with other variables such as altruistic contributions to social wellbeing and amenity value of the land (z_i), as well as with the payment (PES) given as compensation for not developing a hectare of land. Formally agent benefits are $B_{Ai}(PES_i, OP_i, x_i, y_i, z_i)$. The participation constraint implies that the landowner will participate in signing a contract if:

$$B_{Ai}(PES_i, x_i, y_i, z_i) \geq B_{Ai}(OP_i, x_i, y_i).$$

4. EMPIRICAL ESTIMATION ESTRATEGY

This chapter explains empirical modeling and estimation methods employed to derive the social benefits associated with forest conservation and the landholders' opportunity cost function for forest land use. These are the two main empirical issues that must be addressed in order to infer optimal PES levels. The study estimates the maximum PES level that society would be willing to pay in order to avoid forest land conversion to farming along with landholders responses to PES payments. As the social cost of forest loss increases, so do the benefits of forest protection. We only address CO_2 emission and sediment yield as social costs. Furthermore, the study explains factors shaping private benefits and costs of retained land use that underlies program participation.

4.1. Factors affecting private benefits and costs of PES participation

Benefits of participation

There are several factors that affect both the costs and the benefits of participation in the PES program. Factors that increase benefits of participation include the PES payment as direct income, nonmonetary benefits of forest land protection, and social recognition for contributions to conservation if the individual favors conservation. The PES contract in some way is a *de facto* recognition of land tenancy, so participation may also generate land tenure benefits.

4.1.1. Costs of participation: opportunity costs

The distribution of opportunity costs depends on the value of income that could be generated by annual cropland or other activities through the development of forest lands. Factors that increase costs of participation are primarily variables related to land attributes, which determine opportunity costs of land use. Attributes of the land such as soil quality, accessibility, slope, and presence of water determine its productive value. Also, opportunity costs can be influenced by household characteristics such as poverty level, and managerial skills that influence land use options and productivity. The opportunity costs may be a key variable in determining landholders participation because for the majority, farming is the primary source of income. Further, the PES program bears most of the costs for contracts, monitoring and information, so transaction costs are minimal.

Landowners will protect forestland and sign a payment contract if the payment PES_i is at least equivalent to the opportunity cost of bringing the land into agricultural production, forest management, or pasture. They will reject participation if the PES principal's offer is below their opportunity costs of alternative land use. In order to make this calculation, we need to collect information on the range of potential opportunity costs ($OP_{i=1,2\ldots n}$) of farmers.

Productive options for forest lands were first identified by meeting with technicians of public and private organizations currently working in the area, and later validated with farmers. The alternative economic activities identified in order of frequency were: cattle, managed forest, pasture for rent, coffee, and annual cropland. A description of the common arrangement of potential use for lands in the study area is useful to better understand the distribution of opportunity costs. The next paragraphs briefly describe typical arrangements in those farming systems.

Pasture can be used directly by landholders with cattle or for renting out to other ranchers. Pasture and annual cropland cover the largest non-forest area in the study zone. Although there are also milk and beef cattle in the area, the latter is more often on steep slopes where most forests are located. Net annual benefits from beef cattle was estimated in RD$8,000 per hectare (PROCARYN, 2008). Landholders with no investment capital make money renting the pasture (*piso*) to cattle owners. The rental value differs according to the carrying capacity of the land, which depends mainly on slope and type of pasture. Santos (1992) calculated animal-carrying capacity to be between 0.75cow ha^{-1} to 1.25cow ha^{-1} in the Plan Sierra zone. A similar pattern was observed at the study area.

Managed forest is an alternative for private forests, although the majority of forest area is protected under the national system of protected areas (SINAP). Coniferous and mixed needleleaf and broadleaf forests can be used to produce timber. Usually the logged trees are natural or planted pines based on a management plan approved by the Ministry of Environment and Natural Resources for a five-year period. The forest technical standards only allow removing a partial stock from the forest; and by law a forest never can be transformed to agroforestry or any more intensive farming system. However, the economic incentive of developing agriculture and the weak law enforcement drive deforestation and forest degradation.

Coffee is considered a traditional crop in high YNW, both with and without tree shade. Farm sizes range from less than 0.5 hectares to more than 100 hectares and are usually located between 500-1500 meter above the sea level (masl). Coffee production begins in the third year after the bushes are transplanted (Altrieth, Benoit, & Franco, 2002) and continues through year 20, when plants are gradually replaced (Santos, 1992). Management activities include pruning, picking, controlling weeds, shadow, and disease. Even though coffee remains in the zone, growers face the risks of volatility in international prices and diseases. Altrieth et al. (2002) found that on average coffee producers had a negative income of RD$-6,521.73 $ha^{-1}year^{-1}$ (in 2018 price). This outcome is consistent with the studies published by CEPAL (2002) reporting that the coffee market went through an unprecedented crisis. Accumulated overproduction for several years and weak economies in large consumer countries like the US depressed the 2002 coffee price in Latin America and the Caribbean (CEPAL, 2002).

Annual cropland is found in the high YNW mainly in two types of systems, controlled environments (greenhouses) and open-fields with different technological levels. Some crops can be found in both systems such as fruits and vegetables. Among traditional crops cultivated in open-fields are potato, bean, yellow radish, cabbage, flowers and vegetable pear. Farmers use different combinations of rotation cycles ensuring the most convenient rotation sequence for soil quality and weather conditions. For example, a sequence of rotation could be lettuce (45 days)-potato (90 days)-cabbage (60 days)-bean (90 days). Crops usually grown in greenhouses are tomato, pepper, cucumber, and strawberry, among others. Annual cropping is a profitable activity in the area.

Assessing opportunity costs is necessary in the analysis because assuming that landholders have the right to deforest current forest lands, the income they sacrifice represents the private cost of environmental services provision. In theory, the present opportunity cost for preferred and feasible land use should indicate the minimum payment (PES) required for a farmer to maintain forest land.

4.1.2. Participation model

A second step is to model the binary participation choice to better understand the variables affecting the probability of PES program enrollment. In addition to opportunity cost, participation can be influenced by family size, level of education, number of people that work in lands, quantity of land owned by the household, among others. The potential impact of those variables is furthers discussed below.

Based on the review of the literature, the following model is suggested for analysis of participation in the payment program.

(3) $$PES\ contract = \beta_0 + \beta_1 Rentalvalue + \beta_2 Familysize + \beta_3 Solidaridad + \beta_4 Education + \beta_5 Forestland + \beta_6 Forestland^2 + \beta_7 Totalland + \beta_8 Remoteness + \beta_9 Water + \beta_{10} Tenure + \beta_{11} Slope + \beta_{12} ProNEP + u$$

The independent variable in (3) is the participation of households in the PES program. The choice of landholders to participate is influenced by both monetary and non-monetary factors. Profitability of alternative land use activities can affect the owner's decision to conserve. We especially want to assess the effect of the income generating capacity of the land, which largely determines the opportunity cost. One indicator of the income generating capacity value of land is the rental value. Given that the PES program pays a flat payment, as the **rental value** increases, the willingness of owners to accept a PES contract should decrease. However, the magnitude of this relationship is an empirical question to be evaluated using site-specific data.

Family size is a relevant variable in the model because a family's decision on how to use land will affect the wellbeing of the whole family. Land is usually the most valuable asset of a farm households. A large family is likely to demand more land for farming or needs to cultivate larger areas to support all members with food and income. By the same token, more family labor makes a unit of land more productive. In either case the effect on the probability of participation in conservation programs is likely to be negative.

Given the difficulty for measuring **poverty** status, we rely on the official classification of household eligibility for social assistance as an indicator. Households where monthly per capita income is below RD$4,285 (MEPyD-ONE, 2017) qualify to receive subsidies from the social assistance program through a ***Solidaridad*** card. Poverty is hypothesized to be positively correlated with PES participation because poor families gain greater marginal utility from a stable source of income.

Education is always an influential variable in household decisions. Education effects in the participation model can be ambiguous due to correlations with other potential unobserved explanatory variables. For example, an individual with more years of schooling might be more aware of the need for conservation, but that same person might have better skills and financial resources to develop the land. The influence of education is, therefore, left as an empirical question. **Land tenancy**, which is a significant concern in the study area, may be relevant in explaining PES participation. Farmers may accept a payment contract in order to strengthen land tenure if they lack a title.

Land quantity and attribute variables have more predictable effects in the model. Both, hectares of **total land** and **forest land** owned by the household are expected to be positively correlated with PES enrollment. One reason is that for large parcels, it is more likely that some portion cannot be used for any productive purpose. Another potential reason for a positive correlation between land size and PES participation is that households may be risk adverse, thus diversification of land use (including conservation) seems to be advantageous. But, the marginal effect of those variables might not be constant. At some point, the effect of having more lands might be decreasing and a quadratic term accounts for this behavior. Amenity

An ambiguous sign is expected for the presence of **wate**r on the forest parcel. Since water is an important production input, it could increase the potential of the land for cropping, in which case the sign will be negative. However, the usual pattern within the DR is to conserve forests around water bodies especially in mountains, therefore if the amenity value dominates a positive sign can happen. The Dominican Constitution prohibits private ownership on water, and the actions that harm water sources are culturally labeled as crimes. People value water not only as an individual asset, but as a collective one. So, if a household have water body in its property, it assumes the responsibility to take care of the water.

Slope is a physical limitation of land use, therefore it is predicted to have a positive sign in the model. Another important land attribute is **remoteness.** More accessible and less remote lands will have higher opportunity costs for land use and will have lower probability of program enrollment. This variable includes an average of both distances from the nearest road and to the owner's house. In contrast with economic factors is the altruistic attitude of landholders. **ProNEP** as proxy of pro-environmental conservation attitudes may be positively correlated with the decision to participate in the payment program.

4.2. Methods

The PES program participation decision is estimated via a statistical model while social benefits of forest conservation are estimated via simulation. Both methods area discussed below.

4.2.1. Statistical model

A limited dependent variable model (LDV), or more precisely a nonlinear binary response model, allows us to determine the probability of program participation as a function of independent variables that influence the farmer's decision to bring land into the program. We use maximum likelihood estimation (MLE) of the Logit model. The vector X includes variables determining eligibility and affecting the owner's choice. Thus equation (3) becomes:

(4) $$P(y = 1|x) = G(\delta_0 + \delta_1 x_1 \; \ldots + \delta_k x_k) = G(\delta_0 + X\delta)$$

where G is a function taking only values between zero and one. If household participation in the payment program is observed P=1, and P=0 otherwise. The vector X entails the previously discussed independent variables. The decision rule can be represented as follows. Decision $y_n(g,x)= 1$ if the landholder participates or $y_n(g,x) = 0$ if the landholder does not participate.

$$y = \begin{cases} 1 & \delta_0 + \delta_1 X + \varepsilon > 0 \\ 0 \text{ otherwise} & \end{cases}$$

where *y* represents a latent variable (*y'*) not directly observable, but that can be explained by observed variables. The indicator function, y'=1[y>0] takes on value one if (y > 0) is true and zero otherwise. We assume that the error term ε is independent of X, and that ε has the standard logistic distribution.

4.2.2. Value of social benefits

Social benefits from forest ecosystem conservation and other sustainable land uses in the watershed is measured in terms of i) social cost of carbon and ii) cost of reduction in water storage capacity in the dam. Stored water is used for domestic consumption, power generation and agricultural irrigation. Different land covers produce different levels of carbon sequestration and erosion (sediment yield). Therefore, estimation of the amount of CO_2 and sediment retained is done by comparing outcomes of the two variables under forest cover and under the most profitable activity for each forest parcel.

Information on the most profitable activity was provided by landholders in the survey. There are plots where no other activities are feasible. Similarly, there are plots with several potential alternatives and the owner might identify a sole preferred choice, which we assume is the most profitable one. For example, if livestock is a feasible productive activity, an estimation of CO_2 emission under grazing in grassland is compared to forestland use in order to estimate how much CO_2 release is avoided by retaining forest lands. The same approach applies for soil erosion. In summary, the social cost of farmers' land use choices is approximated by the environmental damage and direct economic losses associated with soil loss and CO_2 emissions. Thus we estimated equation (1) for this study based on the social cost of carbon (a) and cost of erosion (b) per hectare of land (q):

$$B_p(q) = a(q) + b(q).$$

4.2.2.1. Carbon change estimation

Estimation of the value of CO_2 emission or removal is conducted in two phases. The first one is the calculation of the quantity of CO_2 that can be emitted due to land use conversion, and then estimation of the rate of net accumulation (gain minus loss) of carbon for one year. The quantity of carbon is inferred from the biomass on the ecosystem. The second phase is to convert of the quantity of carbon into tons of CO_2 and multiply by the social cost of carbon (SCC). The SCC represents the social cost or damage of an additional ton of CO_2 in the atmosphere.

There are various methodological approaches for carbon accounting in land use sources and sinks. The United Nations Intergovernmental Panel for Climate Change (IPCC) has developed a toolkit that is summarized in the 2006 IPCC guidelines. The toolkit provides three levels of estimation details (called Tiers). We are interested only in estimation of GHG for the Agricultural, Forestry, and the Other Land Use (AFOLU) Sector. The inventory of emissions and removals can be calculated for all land use categories; in our case forest land, cropland, grassland, settlements, and other land. The IPCC methodology uses five pools of GHG sources/sinks named biomass separately as above-ground and below-ground, dead organic matter (DOM) –includes litter and dead wood– and soils. Since the DR is seeking greenhouse gas (GHG) reductions through support of the REDD+ program, the 2006 IPCC guidelines provide a good framework for GHG estimation in this study.

Due to data constraints, we use Tier 1 which, although less precise than subsequent Tiers, allows us to use default values in parameters from global data when no site-specific data are available. The estimation of emissions using Tier 1 does not include DOM pools for land remaining as the same land use category. Estimation will retain all the assumptions encompassed under Tier 1 regarding the movements of carbon among pools within any land use category (see

IPCC, 2006 guidelines). Changes in carbon stocks in different land covers are converted to atmospheric CO_2 emissions or removals based on the molecular weight ratio (44/12). The basic equation for calculation consists of activity data (AD) on the extent of area with human land use activities and emission factors (EF), coefficients that quantify emissions by each activity.

$$\text{Emissions} = AD*EF \qquad (5)$$

The steps for carbon inventory with 2006 IPCC guidelines, Tier 1 are the following:

a) Classify all land into land use categories
b) Estimate carbon stock in land use categories
c) Estimate forest land that might be converted to other more profitable land use categories, based on the survey
d) Estimate carbon in the biomass in new land use categories and their sequestration rate
e) Estimate the total change in carbon stock and the carbon sequestration rate for emissions or removals.

Managed land is taken as proxy for anthropogenic effects in carbon flux. This study does not estimate non-CO_2 gases and CO_2 estimation is done only for biomass, both aboveground and belowground. This process assumes no change in carbon stock due to disturbances, reforestation and natural regeneration. We only measured conversion from forest and shaded coffee to other land uses. This implies that lands currently in grassland, cropland, settlement and other lands stay the same (*ceteris paribus*). Although these are not very realistic assumptions, it allows for simplification of the analysis to focus only on forest land conversion. Moreover, expansion of the agricultural frontier is a common driver of deforestation. The Gain and Loss Method is adapted in order to perform the estimate of difference in emissions in land uses.

(6) $$\Delta C_i = C_{iG} - C_{iL}$$

where ΔC is the net sequestered in biomass in a unit of land; i accounts for annual cropland, pasture, and so on; C_G is carbon gained due to biomass growth; and C_L is carbon loss in the same land either transferred to other pools or to the atmosphere.

Social cost of carbon

The second phase of carbon inventory is to compute the monetary value of emissions or removals (negative emissions). Depending on the change, with respect to a certain reference level, the result can be CO_2 removal, not emission. In order to calculate the social cost of carbon we assume that future emissions follow the path of economic incentives of land use that landowners have. Therefore, the estimation of change in emissions is based on expected land use conversion as declared by landholders. In study we use SCC values suggested by the literature in the field (see Stern, 2007; IWG, 2016). Specifically we use US$25 per ton CO_2, but scenarios with lower values are also presented.

(7) $$\text{Net social cost per hectare (a)} = (CO2_{nfc\ I} - CO2_{fc})SCC$$

The net social cost per unit (a) of land is the product of change of CO_2 from conserved forest to other land use times the unit value of carbon. The subscripts represent conserved forest and non-conserved forest with BAU scenario and *i* is the new land use.

4.2.2.2. Soil erosion change under alternative land use

In order to estimate changes and social costs of erosion we follow the method developed by Santos (1992) for Plan Sierra project. As previously explained, the area of transition from forest to other land use was estimate based on data provided by landholders on the survey.

A Universal Soil Loss Equation (USLE) was applied by Santos for estimation of erosion prevented by forest conservation. The USLE is globally used to estimate long-term average annual soil loss (or sediment yield) explained by biophysical and social factors such as soil type, topography, climate, vegetation and management pattern (Kinnell, 2010). The formula was developed to be used on plot-sized surfaces (Molina-Navarro, Martínez-Pérez, Sastre-Merlín, & Bienes-Allas, 2014), thus it is appropriate for this study.

(8) $$A = R\ K\ L\ S\ C\ P$$

where

A is average annual soil loss (mass/area/year)

R is the rainfall–runoff ‘‘erosivity” factor

K is the soil ‘‘erodibility” factor

L and S are the topographic factors that depend on slope length and gradient

C is the crop and crop management factors

P is the soil conservation practice factor.

Erosion is calculated for the different land uses present in the sample. Calculation of the amount of soil loss avoided is done by comparing the estimated erosion in conserved forests with the owner preferred alternative without program intervention. For example, if raising cattle is a feasible productive activity, an estimation of sediment yield in pasture compare with the same for conserved forest indicates how much erosion is avoided through retained forest.

The second step for measurement of erosion is to calculate the amount of soil particles that reach a specific point or reservoir in a given period of time, called sediment yield. Then, the Sediment Delivery Ratio (SDR) can be obtained by dividing the sediment yield by the total erosion corresponding to a certain area. In other words, SDR accounts for the proportion of erosion that will reach the dam in our case. SDR varies in relation to the ecological (biophysical) characteristics of the site. The area under a land use is multiplied by its erosion factor is the soil loss (SL). The result of SL times the SDR indicates sediment yield of this type of land use.

(9) $$SDR = \text{Sediment yield} / \text{Soil loss}$$

(10) $$\Delta SLD_i = (SL_{nfci} - SL_{fc})SDR$$

where ΔSLD is change in soil loss delivered, SL is soil loss, the subscripts represent conserved forest and non-conserved forest with BAU scenario and i is the new land use. The results from equation (10) for each land are converted to volume and expressed in monetary terms.

Social cost of erosion

The social cost of erosion is measure through the value of a cubic meter of space in the artificial reservoir, the Tavera dam. The economic value of erosion will be measured in terms of hydroelectric generation loss due to sediment stored in Tavera dam. Sediment accumulated in a m^3 of the infrastructure reduces the dam's capacity to store the water. Hierarchical priorities of use for water stored in Tavera dam are: i) drinking water, ii) irrigation, and iii) power generation (CNE/EGEHID, 2009). Power generation does not consume water therefore the same water is used in the low watershed for irrigation. Then, the value of a m^3 of dam's space can be determined adding value of these water uses.

(11) $$\text{Unit value of Tavera dam's space } (m^3) = \sum W_i$$

where W is water and its uses are represented by i in equation (11). In order to calculate equation (1) we need the result from equation (11) in term of unit of land area. Results represent the cost of soil erosion at the watershed actually paid by society. Since we only estimate reduction of storage capacity of the dam, this cost is a low bound approximation of the negative effects of erosion on the well-being of people, other related cost is treatment of drinking water. Santos

(1992) estimated dam's space value for Bao watershed adjusted by shadow exchange rate (SER). Conversion factors and references used by Santos and transferred to present study are showed in Appendix 2.

5. DATA

Data are collected on a number of socioeconomic variables related to the private and social costs and benefits of household forest parcels. In the first part of the analysis, information is needed on variables influencing landholders' participation in the PES program, including opportunity costs of forested lands. In the second part, information is required on social benefits resulting from ES provision attributed to forest conservation in YNW, such as soil retention and CO_2 emission reductions. In this section, we provide details on the sources of information and how we derive each variable.

5.1. Primary data: survey

The model of participation in the payment program draws on a unique dataset obtained from a survey of households in communities where PES were offered (see survey questionnaire in Appendix 3). The target survey population is composed of households owning forest and/or shaded coffee at the area of influence of the PES program, the rural zone of Jarabacoa and Constanza in the Yaque del Norte watershed. According to the last census, the rural population in Constanza was 28,293 persons living in 7,639 households; while Jarabacoa has 28,034 persons in 7,934 households (ONE, 2010).

By 2016, the PES program has signed 61 contracts for forest and coffee conservation. A survey of 150 households was conducted in March 2018; the survey gathered information on the lands and landholders. The sample includes 47 PES participants that represent 77 percent of PES beneficiaries. The survey did not include enterprises that receive payments, only households.

Household, defined by the National Office of Statistics (in Spanish ONE, 2007), is understood as one or a group of people depending on a common fund for their expenditures, and who have resided in the same address together for at least the last three months before the survey. The survey respondent is the person in the household who makes decisions about land uses, usually the father or oldest son when parents are very old. If a couple makes decisions on the land together, the interview was completed with both spouses.

First identification of households was made by contacting producer and community organizations. PES participants helped in including in the sample their immediate neighbors that own forest or coffee lands within Yaque del Norte watershed. The final sample only included households owning forest and coffee lands that satisfy established criteria, and located within the YNW area offering payments. The criterion for forest area was the same as used by the payment program; private lands (no protected public areas) with trees covering at least 50 percent of the area. The forest can be natural or planted forest of one hectare or more. Since coffee is subject to PES in the current program, shaded coffee plantations from a half of hectare are also included in the sample.

The questionnaire was administered face to face in the landholders' community by a technician from the Ministry of Environment and Natural Resources of the DR. The survey consisted of 30 questions divided in three groups: i) characteristics of the household owning the land and attributes of farm-head, ii) biophysics attributes of lands and costs and benefits from different farming activities, and iii) landholders' attitude about environmental conservation. Responses were written on paper and then transferred on a spreadsheet. Table 2, defines relevant variables for the participation model.

Table 2. Variables definition for the participation in PES model

Variable	Definition	Unit
I. Household head/farmer attributes		
1. Education	year of education completed by farmhead	Year
2. Family size	number of people in the household	N
3. PES contract	1 if has signed a payment contract	Dummy
4. *Solidaridad*	1 if receives government's subsidies and 0 otherwise	Dummy
II. Biophysical attributes of forest lands (potential or enrolled in the PES program)		
5. Remoteness	Remoteness/accessibility in average distance of a forest parcel from the nearest road, and owner's home. If PES contract, these referred to the enrolled parcel	Km
6. Slope	how steep is the forest parcel	Percent (%)
7. Water	number of sources/bodies of water within the parcel	N
8. Tenure	1 if titled and 0 otherwise	Dummy
9. Rental value	Self-reported market value of forest parcel if rented out	RD$ha^{-1}year ha^{-1}
10. Forest land	Area of forest land owned by household	hectares (ha)
11. Total land	All land area owned by household	hectares (ha)
III. Attitude of landholders on environmental conservation		
12. ProNEP*	1 if pro-NEP and 0 otherwise, according to response of statements about relationship between humans and the environment.	Dummy

Notes: *Revised New Environmental Paradigm –NEP, Dunlap et al. (2000).

Table 3 presents descriptive statistics for variables included in the model. The sample for the model consists of 141 observations with complete information on all variables employed in the model, from which 31.3 percent have a PES contract. The size of households in the sample ranges from 1 and 10, with 3.8 as the mean value. The average education level is 6.5 years, which is less than elementary school completion. The survey also established whether the household was classified as poor, based on receipt of government assistance through a *Solidaridad* card. By that criterion, 48.2 percent of households are poor in the sample. Land tenure could be an important factor to assess owners' decisions, and only 22.7 percent of parcels have formal title (tenure).

Table 3. Summary statistics of model variables

Variable	Obs	Mean	Std. Dev.	Min	Max
PEScontract	141	0.31	0.465	0.00	1.00
Rentalvalue	141	10572.24	12740.930	111.50	80000.00
Familysize	141	3.86	1.827	1.00	10.00
Education	141	6.32	5.019	0.00	20.00
Solidaridad	141	0.44	0.498	0.00	1.00
Forestland	141	48.78	87.309	1.00	500.00
Totalland	141	61.45	106.046	1.44	625.00
Remoteness	141	6.06	6.686	0.00	46.00
Landtenure	141	0.24	0.429	0.00	1.00
Water	141	2.01	1.880	0.00	14.00
Slope	141	33.88	13.414	5.00	70.00
ProNEP	141	0.43	0.497	0.00	1.00

Source: Landholders survey, 2018

The survey collected several variables in order to measure accessibility/remoteness of forest parcels. On average, parcels are located around 6 km from owners' homes and/or from the nearest road. The Remoteness variable value is the mean of the two distances. In contrast to other studies that calculated distance from a network road map (see Taylor & Susilawati, 2012), this information was provided by landholders. Given the small area and the risk of having an outdated road map, self-reported distance may be more reliable.

The distance from the nearest road is very important for developing the land. It is also recognized that accessibility varies for different types of road. A paved road provides better access than a dirt one. However, this study did not classify road type; any access that allows crossing of a vehicle typically used for transportation of agricultural products was counted. Even though proximity to market is usually the most important variable, it does not apply to our study because there are two urban centers in the zone (Jarabacoa and Constanza), but their demand for agricultural products is far below farms' output. In other words, they are not the market centers that matter for the analysis. Usually, trade occurs between farmer and intermediary at the nearest road to the farm. Therefore, distances from road and from the home provide the best measure of accessibility.

Areas and potential rental value of current forest and coffee lands were reported by landholders. Given the target population, all respondents own at least a forest parcel and/or a coffee parcel. Farmer estimated rental values range from RD$111.50 to RD$80,000.00 $ha^{-1}year^{-1}$, with a mean of RD$11,848.10 $ha^{-1}year^{-1}$. The mean size for all forest parcels is 48.24 ha, with values ranging from 1 ha to 500 ha. Some characteristics specific to forest and coffee parcels are worth mentioning. On average, the slope is 33.6 percent which means that land use is heavily limited, especially if soil erosion is a concern. Plots frequently have water bodies, with an average of almost two water sources per plot on the sample.

The last set of variables in the survey accounted for respondents' attitude about conservation. The survey included six items from the New Environmental Paradigm (NEP) developed by Dunlap, Van Liere, Mertig, and Jones (2000), as a standardized scale for assessing a person's conservation awareness. NEP's items might help to explains landholders' PES participation response beyond pure economic profits. Agreement with three pro-NEP statements and disagreement with three non-NEP statements show individual's pro-environment attitude. Unfortunately, it was difficult to standardize responses or avoid misunderstanding for some questions. Farmers had difficulty in giving consistent answers for most NEP's items. Farmers who only know their villages could not envision the entire world when answering questions about global issues.

For this reason, instead using likert scale summation, we created a dummy variable that reflects in more general terms landholders` attitudes. First, responses were transformed so that the increase in value is consistent with a person's position of agreement or disagreement. Given the six items with responses from one to five, the maximum possible points were 30. We set a cut off value at 16: observations with $\geq$16 points were classified as pro-NEP and observations with fewer points as non-NEP.

Table 4. Summary of land value and income per land use (RD$ ha^{-1} year^{-1})

Land use/value	Obs	Mean	Std. Dev.	Min	Max
Salevalue	150	439,079.90	491,819.60	13,271.40	2,400,000.00
Rentalvalue	148	11,848.10	15,053.13	111.50	80,000.00
ForestIncome	5	13,761.00	0.00	13,761.00	13,761.00
CattleIncome	8	14,841.84	10,066.78	1,760.00	33,638.74
CoffeeIncome	13	17,631.20	25,015.46	-4,698.80	82,285.71
A.cropland Income	77	251,970.10	333,978.10	-92,250.00	1,811,800.00

Source: Landholders survey, 2018

A primary goal of the survey was to collect updated information about opportunity costs from alternative uses of lands (Table 4). Farmer estimates of the value for sale of one hectare of land ranges between RD$13,271.40 and RD$2,400.000.00. We only interviewed forest and coffee land proprietors, and among them we collected information on farming activities they completed during the last year (2017). Income values reported from few observations must be used with caution. We provide more details below about the bias that may occur.

In the sample, 51.3 percent of respondents do some farming. Values from productive activities represent reported gross income without subtracting labor costs, except for forest management. Labor intensity varies per land use; for example, livestock needs far less labor than annual cropland. Labor costs are relatively high for annual agricultural crops grown on the area. The production of vegetables, fruits, and flowers is the most profitable farming activity in the area. The average gross income reported was RD$251,970.10 ha^{-1}year^{-1}. Annual cropland is followed by coffee in profitability. The average income from a coffee plantation was RD$17,631.20 ha^{-1}year^{-1}, which reveals the fact that coffee growers are fighting to keep coffee farms despite the devastating effects of coffee rust caused by *Hemileia vastatrix* in recent years. Using the eight observations of pasture land with cattle, the mean income for cattle growers is RD$14,841.84 $ha^{-1}year^{-1}$.

It was difficult to come up with an accurate estimate of the income generated from forest lands because owners neither know the age of their forests, nor have recorded data about past harvesting and revenue. In order to estimate the income from managed forests we made three assumptions. i) *Pinus occidentalis* (*pino criollo*) is virtually the only wooden species harvested in the study area, ii) mean annual increment (MAI) in volume of *pino criollo* on the country is 6.2 $m^3ha^{-1}year^{-1}$ (Bueno, 2014) to 7.7 $m^3ha^{-1}year^{-1}$ (Diaz & Montero, 2010), which gives us an average of 6.95 $m^3ha^{-1}year^{-1}$, and, iii) the annual volume of harvested wood is exactly the annual growth of forest. The basis for this assumption is that for more than 30 years the forest authorities do not allow the cutting of all trees, the maximum that can be taken off is what the forest produces annually, in order to ensure sustainable forest cover. Using the price of wood (RD$20 PT^{-1}), productivity of a cubic meter (180 PTm^{-3}), and given that forest producers report associated costs as being 0.45 of gross revenue, the income from managed forest, turned out to be RD$13,761 $ha^{-1}year^{-1}$. In the case of forest, the income does include labor. Those income values from different land uses represent private cost of forest conservation in our analysis.

5.2. Data for social benefits

5.2.1. Data for carbon change and social cost of carbon

In order to calculate the social benefits from CO_2 sequestration using the 2006 IPCC guidelines, we need to choose emission factors according to biophysical characteristics of the study area. Table 5 depicts default emission factors and parameter used in the carbon inventory from IPCC global database, unless otherwise indicated. The climate zone in the project area is tropical montane moist and dominant woody species is *Pinus occidentalis* in natural forest. Emissions in the AFOLU sector depend on management practices applied for each land use and local environments conditions.

Table 5. Emission factors used for carbon stock and sequestration rate

Emission factor	value	Unit
Forest land		
Aboveground biomass in forest*	111.41	ton d. m. ha^{-1}
Carbon fraction of biomass	0.5	ton C ton^{-1} d. m.
Ratio of belowground biomass /aboveground biomass (R)	0.27	ton d. m. $(ton\ d.\ m.)^{-1}$
Aboveground growth in merchantable volume (G) (MAI)	7	$m^3 ha^{-1} year^{-1}$
Biomass growth (G_{Total})	6.22	ton d. m. $ha^{-1} year^{-1}$
Aboveground biomass loss (L)	4.9	ton d. m. $ha^{-1} year^{-1}$
Biomass conversion and expansion factor for commercial volume (BCEFs)	0.7	ton d. m. m^{-3}
Wood density-pine (D)	0.51	ton d. m. m^{-3}
Cropland (perennial=coffee)		
Aboveground biomass*	78	ton d. m. ha^{-1}
Biomass accumulation rate (G)	2.6	ton C $ha^{-1} year^{-1}$
Cropland (annual)		
Aboveground biomass (G)	5	ton C ha^{-1}
Grassland		
Total biomass stock	16.1	ton d. m. ha^{-1}
Settlement (summer houses)		
Aboveground biomass	78	ton d. m. ha^{-1}
Conversion factor C to CO_2	44/12	CO_2/C

Note: d. m.=dry matter
Source: Based on 2006 IPCC Guidelines and *FNI-DR (2016)

Table 6 shows a conversion matrix of forest and coffee lands that are expected to change use in the future. The matrix was computed using the 2006 IPCC guidelines approach 2 for data collection, and based on information provided by landholders on the survey. The projection of land use conversion reflects a change from forest or coffee to the activity that they identify as most profitable for each parcel. Every respondent were asked what is the most profitable productive activity for current forest parcels. Then we added the parcel areas projected to be in the same land use.

Table 6. Land use conversion matrix of forest land from the sample (hectares)

Land use category	Forest (conservation)	Forest (wood production)	Grassland	Cropland annual	Cropland perennial/coffee	Settlements	Other land	Final total
Forest (conservation)	1693.18							1693.18
Forest (wood production)	1831.80	966.25						2798.05
Grassland	814.32		835.99					1650.31
Cropland annual	701.00			381.67	1.50			1084.17
Cropland perennial/coffee	735.78				200.69			936.47
Settlements	156.25					0.00		156.25
Other land							418.18	418.18
Initial total	5932.33	966.25	835.99	381.67	202.19	0.00	418.18	8736.61
Net change	-4239.15	1831.80	814.32	702.50	734.28	156.25	0.00	0.00

Source: Computed from Appendix 4

For example, 20 households stated that the most profitable use is cattle. Then, the summation of areas of those 20 parcels (814.32 ha) gives the forest area that would be converted to pasture. Similarly, the area in the cell forest conservation, forest conservation (1,673.44 ha) is the total areas of the plots whose owners expressed conservation as the most appropriate use for the land. Using our sample and assuming that only conserved forest lands are converted, it will change from 6,474.21 ha to 1,702.57 ha, an upper bound reduction of 73.7 percent. Nevertheless, this does not imply a significant change in the type of land cover, the change is mainly to managed forest. Managed forest would change from 11 percent now to 32 percent. Also, 1.5 ha in current coffee land will be converted to annual cropland. This number seems to be realistic because it is logical that the land may have some use that generates income to the owner, in the absence of the PES program. Only 26 of the lands would remain dedicated to conservation, which probably corresponds to the areas of water sources protection with very steep slopes. Appendix 4 presents data used to derive Table 6.

5.2.2. Data for erosion and social cost of erosion

Data for expected soil erosion and its social cost comes from Santos (1992). He estimated soil erosion for Sierra zone (Bao, Amina and Mao watersheds) using the USLE, and a sediment delivery ratio of 0.5 in the long term. This is an area adjacent to Tavera dam, our study area, and both areas share very similar ecological characteristics. Table 7 shows erosion factors adapted for this study. The erosion factor for coffee (162.1 ton $ha^{-1}year^{-1}$) was computed as the average from four different ages of coffee plantations estimated in Santos' work.

Table 7. USLE erosion factors per land use for the Sierra zone, DR

Land use	Cropping system	Erosion factor (ton $ha^{-1}year^{-1}$)
Forest	Unmanaged forest	25.11
	Managed forest	50.23
Coffee	Average age-coffee	162.10
Mixed cropland	Traditional *conuco*	572.29
Pasture	Beef cattle	110.74

Note: R, SEA 1992; K, LS Plan Sierra Survey Data 1990; C, Plan Sierra Survey Data and SEA 1981; P, SEA 1981.
Source: Adapted from Santos (1992)

The erosion factor used for annual cropland is Santos' estimation for traditional *conuco*, which is the closest equivalent to the variety of cropland systems currently used at the study area. Given that a traditional *conuco* included a mix of crops, some of them perennial ones such as pigeon peas (Santos, 1992) and usually omitted intensive tillage, erosion from current agricultural lands in Jarabacoa and Constanza, *ceteris paribus*, might be higher. Nowadays in the DR, farming implies more mechanized tillage of soils and agricultural plots tend to be larger. On the other hand, the slope variable used by Santos was 50 percent while the average slope in our study area is lower (33.6 percent). We believe that the difference in variable values offset each other, therefore the estimation of soil loss from annual cropland in the Sierra zone is applicable to our area.

Settlement is a land use category not included in Santos' work. This comes from a forest land converted to fallow. The forest land areas converted to settlements, usually keep forest cover partially around a summer house. In the first year after conversion, a higher rate of erosion would be produced due to the construction of housing infrastructure, but stabilization is expected in sequential years. Based on land cover characteristics observed in those farms, we assume the same erosion factor as for coffee.

6. RESULTS

This chapter reports results on private and social costs of forest conservation in YNW. Results include survey reported estimates of the opportunity cost of forest land, factors influencing PES participation, and the evaluated social benefits of forest conservation.

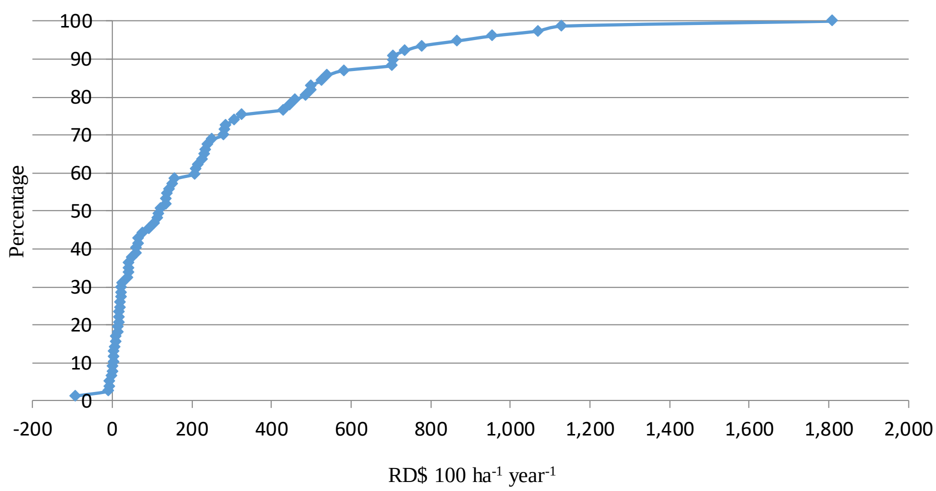
6.1. Private costs of forest conservation

We examine private income from land uses to determine the minimum payment that landholders should be willing to accept as compensation to induce forest conservation. The results of land use income are presented and related to other variables of the target population. It is assumed that PES participation requires compensation equivalent to the potential income generated by the land. Higher opportunity costs of land mean lower probability of forest conservation and higher required PES payments. We present the findings of estimated income from productive land use activities.

The main source of income for 63.3 percent of households comes from farming, with an average of 1.4 persons from each family working in agriculture. Table 4 (in chapter 5) presents a summary of findings for opportunity costs by land use category. The number of observations differs greatly by category because the target population for the survey was landholders with forest and/or coffee. We did not generate a fixed sub-sample for each alternative land use. Instead, the respondent provided data for one alternative land use activity performed in the previous 12 months. This approach made it easier for them to remember the revenues and production expenses.

Annual crop was the most common activity with 77 observations. On the other hand, there were only five for forest (managed forest). In fact, only three with forest management plans harvested in the previous year. Two more provided information from wood recently sold but harvested one year before (see Appendix 4). The number of observations in each alternative land use provides an approximation of the relative frequency of the activity in the zone. In addition, in interpreting these values we must subtract labor costs except for managed forest. Since households usually provided their own labor for farming, they do not have specific data for labor inputs.

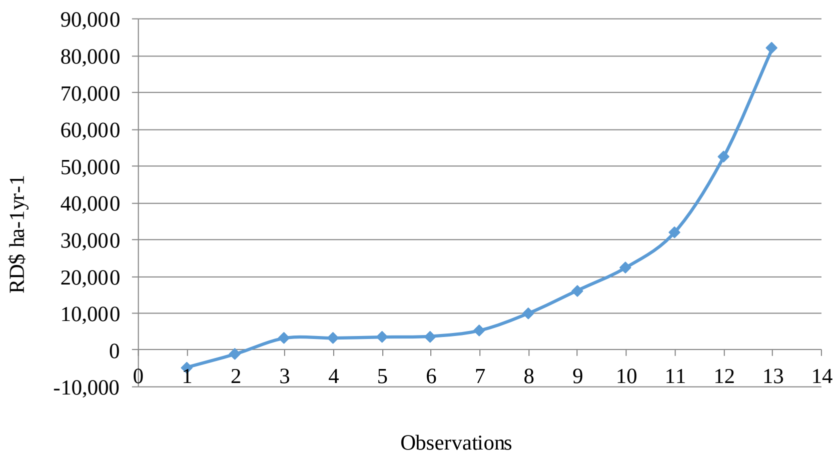
Figure 2. Cumulative frequency of annual income from one hectare of annual crops



Source. Landholders survey, 2018

There is a large range of estimates (Figure 2) of annual crop income per hectare. Income depends primarily on crop varieties and technology used by each farmer. While some farmers still use traditional practices, others have migrated to greenhouse systems, which are more efficient. In the sample, at least five respondents have greenhouse structures and they have the highest income. Annual cropland includes more than ten different crops, including flowers, vegetables, and fruits that generate the highest incomes. As individual crop, vegetable pear, was the most frequent crop listed, with 29 observations. The average annual gross income was RD$251,970.13 $ha^{-1}year^{-1}$. A ranking of all land use activities in YNW, sets the first position to annual crops.

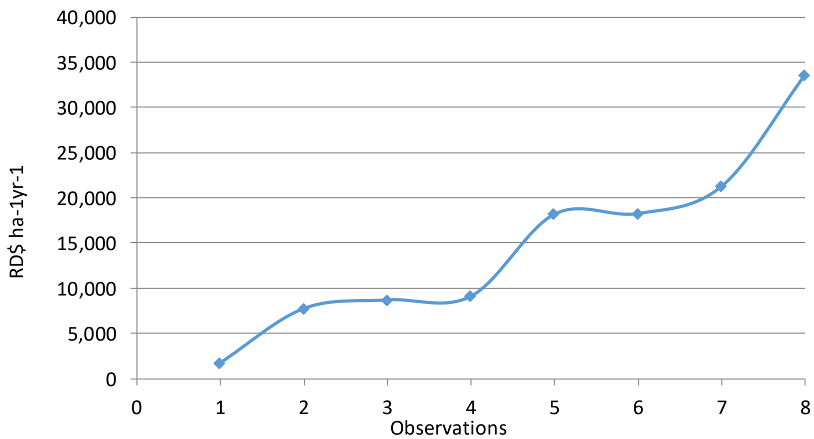
Figure 3. Annual income from one hectare of coffee



Source: Landholders survey, 2018

The distribution of income from coffee (Figure 3) shows a large variability from minus zero to more than RD$80,000 $ha^{-1}year^{-1}$. And Figure 4 presents the distribution of annual income from one hectare of pasture. In the sample the income ranges from less than RD$5,000 to almost RD$35,000 $ha^{-1}year^{-1}$. If we assume labor costs of 30 percent, agricultural income is still far greater than the other activities. In fact, it is almost 13 times the income from managed forest. Altrieth et al. (2002) found that labor costs represented 35 percent of variable costs for traditional agricultural crops in the YNW. Changes in production technologies (e.g. greenhouses) may have reduced labor costs while increasing input costs in the last decade. Consequently, given the profitability of annual cropland in the area, it is very attractive for forest lands to be converted to it.

Figure 4. Annual income from one hectare of pasture

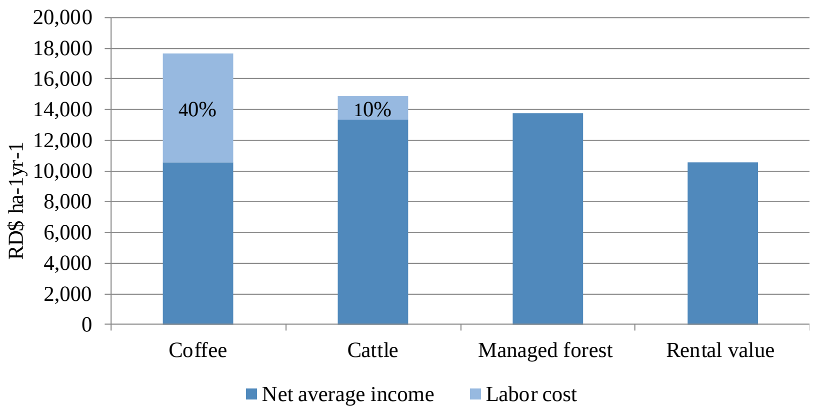


Source: Landholders survey, 2018

Figure 5 shows three categories of land use and their reported average annual income from one hectare in Dominican pesos (RD$). The Figure also shows labor costs in usually accepted rate. If we include labor costs (e.g. 40 percent for coffee and 10 percent for cattle), forest management produces the highest net annual income, almost RD$14,000 ha-1year-1. The average net income from pasture would be RD$13,357.65 ha-1year-1. Despite the small number of observations, our result is similar to that in PROCARYN (2008), which is equivalent to 13,657.72 in 2018 price for pasture annual income per hectare. Net benefit generated by coffee would be RD$10,578.72 ha^{-1}year^{-1}. Thus, managed forest is a land use with economic merits to be developed in the zone.

Figure 5 also presents the average rental value landholders would expected if decide renting the forest land. A next section will explain how a conserved forest is converted to cattle and coffee. Interestingly, the average net incomes from coffee, cattle and managed forest are above average reported rental value of current forest lands.

Figure 5. Net average income and percent of gross income spent on labor from different land uses



Source: Landholders survey, 2018

6.2. Participation model results

Results of the participation model are shown in Table 8. The discrete indicator for having a PES contract is regressed on eleven independent variables. Self-reported perceived rental value is intended to measure the effect of the opportunity cost of the land. The model results for the magnitude of rental value imply that opportunity cost, although consistent in sign with our expectations, is not statistically significant in the PES program participation decision.

Table 8. Results of logistic regression for PES participation model

	A	B	C	D
PEScontract	**Coef.**	**Std. Err.**	**P>|z|**	**dy/dx**
Rentalvalue	-0.0000118	0.0000225	0.599	-0.0000018
Familysize	-0.3888042	0.1402820	0.006	-0.0603686
Education	0.0464687	0.0502255	0.355	0.0072151
1.Solidaridad	-0.6492338	0.4730475	0.170	-0.1006839
Forestland	0.0427687	0.0198552	0.031	0.0061541
Forestland^2	-0.0000320	0.0000174	0.066	
Totalland	-0.0276124	0.0175362	0.115	-0.0042873
Remoteness	0.0529991	0.0307496	0.085	0.0082290
1.Tenure	-0.5301512	0.6464691	0.412	-0.0796779
Water	0.1173972	0.1258942	0.351	0.0182280
Slope	0.0477470	0.0177547	0.007	0.0074136
1.Pro-NEP	1.0010610	0.4506323	0.026	0.1606203
_cons	-2.0914970	1.0018740	0.037	

Notes: Obs, 141; Prob > chi^2, 0.0000; Pseudo R^2, 0.2372

It means that opportunity costs, as measured in the study, are not important in the decision to place land in conservation under a PES contract. This statement can not be generalized to all lands in the study zone. The sample only consisted of households that own forest lands, and some of them also have agricultural land. It is rational to believe that those families are already using the lands they desire, and income-generation from land areas currently with forests is less important. The results also suggest that the PES participation decision may be relatively unresponsive to PES payment levels, as payment flows from land are not driving the participation decision.

The results also suggest other factors that are relevant to the PES enrollment decision. Family size, forest land extension, remoteness, slope and pro-NEP are significant variables at least at the 90 percent significance level. The effects of these variables are consistent with our predictions. Taking an average-size family, the presence of an additional person in the household reduces the probability of participation by six percent. According to slope's marginal effect (Table 8, column D), The economic influence of slope is sizable. A 10 percent increase in slope increases participation by 7 percentage points. Similarly, a 10km increase in accessibility increases the probability of participation by 8 percentage points. The marginal effect of the ProNEP variable, measuring conservation awareness, implies that individuals with ProNEP attitude are 16 percent more willing to participate in the PES program than those with an opposite view. This result may imply that ecological awareness, rather than PES level, is the main driver of owner's decisions to conserve the forests.

The results also show that total land and *solidaridad* just fail to be significant at conventional levels. They might become significant in a larger sample. The negative sign on total land is not consistent with our expectations. Perhaps because with more land (e,g. large pasture), other more profitable income-generating alternatives emerge. The sign and magnitude of the coefficient on *solidaridad* is also unexpected. A positive effect was expected under the assumption that poor households would prefer the stable income provided through the PES contract. A possible explanation is that *solidaridad* is not a good proxy of poverty, but card possession might be linked to political affiliation. It could be also that poor households face more pressure to maximize income from their land, thus they cannot afford to indulge in environmental amenities associated with PES payments. The marginal effect indicates that a household with *solidaridad* has a 10 percent lower probability of participation. But, again, this effect is not statically significant. The relationship between participation in the PES program and poverty is a variable of interest in this research due to the interest of funders in alleviating poverty through investment in conservation.

The results also indicate that other factors are not relevant to the PES enrolment decision (e.g. education, tenure and water). But the statistical significance of estimates should be viewed in light of the relatively small sample size. Having a title to land is also not statistically significant.

How do the participation model results compare to previous survey results on opportunity costs? In summary, rental value of land does not matter for household decisions to enroll land in the PES program. Furthermore, household characteristics and land characteristics matter. Thus, there is potential to tailor the PES program based on these characteristics.

There must be an explanation to reconcile the results of the model and economic assumptions related to forest conservation through a PES contract. One possibility is that current PES participants are nature lovers who did not decide forest land conservation base on monetary factors. Another explanation relates to a selectivity problem in the sample. In any case, further research is needed to understand forest landowner responses to PES payments.

6.3. Social benefits of forest conservation

We now report estimated social benefits of retained forest land in order to infer the maximum PES payment that can be paid to induce forest conservation. The results focus on benefits generated from retained carbon and soil.

6.3.1. Projected land use change

Current and expected land use conversions were investigated through the survey of landholders conducted for this study and previously described. Table 9 presents net change in quantities of land areas for each land use category based on actual and expected (most profitable) land use. Projected change implies that unmanaged forest on the sample could be reduced around two thirds. The other four land uses would gain area: managed forest would increase three times; grassland would double, while annual cropland would multiply by three.

Table 9. Expected conversion from conserved forest to other land use based on landholders survey

Land use category	Actual area (ha)	Expected area (ha)	Change (%)
Forest (conservation)	5,932.33	1,693.18	-71.46
Forest (wood production)	966.25	2,798.05	189.58
Grassland (pasture)	835.99	1,650.31	97.41
Cropland (annual)	381.67	1,084.17	184.06
Cropland (perennial=coffee)	202.19	936.47	363.16
Settlements	0	156.25	0.00
Other land	418.18	418.18	0.00
Total	**8,736.61**	**8,736.61**	

Source: Computed from Appendix 4

Coffee is the use that would gain, relatively, the most area, close to five times actual land area. However, we have seen a decreasing trend in coffee areas due to coffee diseases and international price volatility. It is possible that transition to coffee is only a temporary change, with the final intent to move to vegetable pear. When the forest has been partially cleared, due to implementation of a forest management plan or due to unauthorized wood extraction, farmers start planting coffee bushes. Later, the coffee plantation is converted to vegetable pear, which requires a heavy tree pruning. Finally, annual crop is established because vegetable pear produces higher income than trees or coffee. Authors of a study published in 2006 interviewed 146 coffee growers and determined that 2.3 percent (80 ha) of coffee land was converted in vegetable pear between 2001 and 2006 (CCJ, 2006). These changes occur at the margin of law. Land users behave in a very subtle manner, making it difficult to avoid the conversion.

Grassland is the land use category that would gain the smallest relative area, but historically, the transition of conserved forest to pasture or annual cropland starts with selective tree harvesting. In most cases, this transition is followed by grazing with a very small load. Then, tree elimination continues little by little and finally pasture is permanently established

In the survey we asked respondents "*which do you think is the most profitable productive farming activity in the forest parcel?*". Their responses in terms of potential forest conversion play a key role in our analysis. We comment on three important responses. First, only 18 parcels of 143 (see Appendix 4) are expected to remain with forest conservation in the future. This finding is consistent with the observed confrontation between forest landholders of Jarabacoa and Constanza and the authorities of the Ministry of Environment and Natural Resources. When land owners faced the refusal of the authorities to implement forest management, they subtly changed the land use. Sadly, forest conversion, as we will see in the next section, imposes unaccounted for costs on society.

Second, although conserved forest conveys high social benefits, the expected conversion of forest seems to be consistent with the PES objectives. Despite the fact that overall annual crop is the most profitable activity for land owners, only thirteen parcels in the sample (11.8 percent of current forest area) list annual crop as the alternative most profitable use. But this result should be viewed with caution. Since the survey was applied by technicians from the Ministry of Environment and Natural Resources, respondents may state an activity that they know is compatible to the PES program interest. Thus, the landholders' choice may be influenced by their desire to please the interviewer.

Third, the potential land use that received the most responses was managed forest (44), followed by coffee (38). This result indicates that respondents may think managed forest is a feasible land use. The majority of current forested lands do not have potential for agricultural development, given their conditions (e.g. slope and accessibility). Thus, if the majority of the conserved forests are going to be converted only to managed forests and coffee plantations, in the BAU scenario, the provision of ES on the watershed does not face a strong threat because managed forest and coffee produce, relative low values in terms of the externalities assessed in this study. But, implementation of forest management plans requires the openness of forest authority to allow and to control forest management. In summary, results demonstrate that economic pressure does exist for forest conservation to be converted to other land cover or to managed forest (other land use, but same cover) that increase income.

6.3.2. Carbon and its social cost

Both carbon stock and annual sequestration rate are taken from 2006 IPCC parameters. Values associated with forest are compared with the land use survey that respondents stated as the most profitable.

Table 10. Change in biomass carbon stock due to expected conversion from forest to other uses

Land use	CO2 Stock (ton ha^{-1})	Net change CO2 (ton ha^{-1})	Actual CO2 Stock (ton)	Expected CO2 Stock (ton)
Forest (conservation)	259.40	0.00	1,538,844.13	439,208.95
Forest (wood production)	247.99	11.41	239,619.97	693,887.35
Grassland (pasture)	29.52	229.88	24,675.64	48,711.65
Cropland (annual)	18.33	241.07	6,997.28	19,876.45
Cropland (perennial=coffee)	181.61	77.79	36,719.73	170,072.32
Settlements*	181.61	77.79	0.00	28,376.56
Total			**1,846,856.74**	**1,400,133.27**

Notes: * Same as coffee
Source: Computed from Tables 5 and 9

Table 10 shows biomass change in CO_2 stock due to conversion. If the projection of land use change occurs, 446,723 tons of CO_2 would be released into the atmosphere, and on average the stock of CO_2 would decrease by 51 tons per hectare. Although this change is only an upper bound scenario, it is reasonable to expect that some forest land will be completely converted to annual cropland and some forest portion would be degraded. The non-forest conservation land uses included in this analysis have been identified among direct drivers of deforestation: 1) agricultural expansion, 2) livestock expansion, 3) wood production, and 4) infrastructure (settlements) (Ovalles, 2011).

In reality, those conversions are already happening in the territory, but are not being counted in the official reports that only account for final land area in each category. Ovalles (2011) found that pasture and annual cropland increased from 16,722 ha to 24,355 ha during 2003 and 2010 in YNW but forest only increased 830 ha in same period, likely due to the reforestation efforts since 1997. Biomass density is being depleted over time. A spatial analysis of the dynamic land use change provides evidence of this trend.

Table 11. Carbon sequestration rate on biomass per land use (ton $ha^{-1}year^{-1}$)

	A	B	C
Land use	**C**	**C Difference**	**CO_2**
Forest (conservation)	3.11	0.00	0.00
Forest (wood production)	0.66	-2.45	8.98
Grassland (pasture)	0.00	-3.11	11.41
Cropland (annual)	0.00	-3.11	11.41
Cropland (perennial=coffee)	2.60	-0.51	1.88
Settlements*	2.60	-0.51	1.88
Other land	n/a	n/a	n/a

Notes: * Same as coffee
Source: Computed from Tables 5 and 9

For purposes of this paper, we also need the estimation of the annual carbon fixation rate for each land use category, because we must compute an annual rate value of forest benefits comparable with payment levels for the same period. Table 11 presents values that account only for the annual biomass net gain. Column A shows the rate of carbon sequestration per land use. Forest in conservation fixes 3.11 tons of carbon per hectare annually; it differs with forest in wood production by the amount of harvested wood. Unmanaged forest is followed by coffee, for which one hectare fixes 2.60 tons of carbon yearly, and the same value is assumed for settlements. IDIAF (2010) reported an average of C 3.7 ton $ha^{-1}year^{-1}$ for coffee plantations in Soliman and Juncalito, RD. The lower value in our estimates may be due to exclusion of non-biomass C pools (dead wood, litter and soil). The method used assumes that all biomass gained in one year in grassland and annual cropland is either emitted to the atmosphere or transferred to other pools in the same year. Therefore, the sequestration rate is zero for those two categories. The differences between conserved forest and the other land uses are shown in column B, and column C displays the same converted to tons of CO_2.

Table 12 presents social costs of carbon for the difference in emissions with respect to conserved forest and alternative land uses, and Table 13 shows the same for conversion of land use. Columns A to D present the SCC at US$25 ton^{-1}, 20, 15, and 10 respectively, converted to Dominican pesos. In contrast with erosion that causes a local externality, carbon emission is a global externality, which has no site-specific social cost.

Table 12. Social cost of difference in annual CO_2 emissions per land use

Land use	A	B	C	D	F
	CO_2 (ton ha^{-1}year^{-1})	Social cost (RD ha^{-1}year^{-1})*			
		1,235	988	741	494
Forest (conservation)	0.00	0.00	0.00	0.00	0.00
Forest (wood production)	8.98	11,094.42	8,875.53	6,656.65	4,437.77
Grassland (pasture)	11.41	14,089.91	11,271.93	8,453.95	5,635.96
Cropland (annual)	11.41	14,089.91	11,271.93	8,453.95	5,635.96
Cropland (perennial=coffee)	1.87	2,316.24	1,852.99	1,389.75	926.50
Settlements	1.87	2,316.24	1,852.99	1,389.75	926.50

Note: *1US$=49.40RD$, 6/2018 price
Source: Computed from Table 11.

At least two restrictions are important in interpreting these values. First, they include only sequestered carbon on biomass (aerial and root components). Assuming that annual merchantable volume in forest is 7 m^{3}ha^{-1}year^{-1}, if this value is harvested in managed forest, the net change in above-ground biomass is zero. Further analysis of wood usage will reveal if carbon is truly released in the same year, as it is assumed for this study. Similarly, for cropland and grassland, the annual increment in biomass is harvested in agricultural yield or consumed by animals. It is true that some GHG is emitted from soils in cropland and grassland. Also, some carbon is fixed in soils and dead organic matter (DOM) exists in forest and perennial cropland (coffee), but those pools are not part of this analysis.

Table 13. Social cost of difference in CO_2 stock per land use

Land use	A	B	C	D	F
	CO_2 (ton $ha^{-1} year^{-1}$)	Social cost (RD $ha^{-1} year^{-1}$)*			
		1,235	988	741	494
Forest (conservation)	0.00	0.00	0.00	0.00	0.00
Forest (wood production)	11.41	14,091.35	11,273.08	8,454.81	5,636.54
Grassland (pasture)	229.88	283,905.44	227,124.35	170,343.27	113,562.18
Cropland (annual)	241.07	297,716.86	238,173.49	178,630.12	119,086.74
Cropland (perennial=coffee)	77.79	96,070.18	76,856.14	57,642.11	38,428.07
Settlements*	77.79	96,070.18	76,856.14	57,642.11	38,428.07
Total	**637.94**	**787,854.01**	**630,283.21**	**472,712.40**	**315,141.60**

Notes: *Same as coffee; **1US$=49.40RD$, 6/2018 price
Source: Computed from Table 10.

Second, non-CO_2 gas emissions are not estimated in this research. Since annual cropland/livestock are sources of other gases such as Methane (CH_4) and Nitrous Oxide (N_2O), accounting for those gases will only increase the social value of forest relative to alternative land uses. In this sense, the value provided by this study is a lower bound. Given that non-estimated carbon pools can be more significant in conserved forest than in the other land use categories, the addition of those pools would increase the difference between initial and final stock and average carbon sequestration rate. In other words, inclusion of other pools and all relevant GHGs will change the results of the analysis.

6.3.3. Erosion and its social cost

Results on the volume and social cost of erosion that end up in the Tavera dam are presented in Table 14 in terms of the quantity of soil that reaches the dam from a hectare of each land use. Results indicate that managed forest generates two times the erosion than conserved forest. In fact, given that the average slope at the area is more than 30 percent and that wood dragging is done with oxen, erosion is likely to have an even more significant negative effect in managed forest.

Pasture yields four times as much erosion as conserved forest. The quantity of soil loss from grassland is influenced by the animal load and by the type of biomass present. Silvopastoral systems and improved pasture are suggested as means to reduce erosion in hillside cattle grazing. Also, reduction of the amount of animals can be an effective way to decrease the rate of erosion, because of soil compaction and denser ground cover.

Table 14. Volume of soil delivered to reservoir by land use category

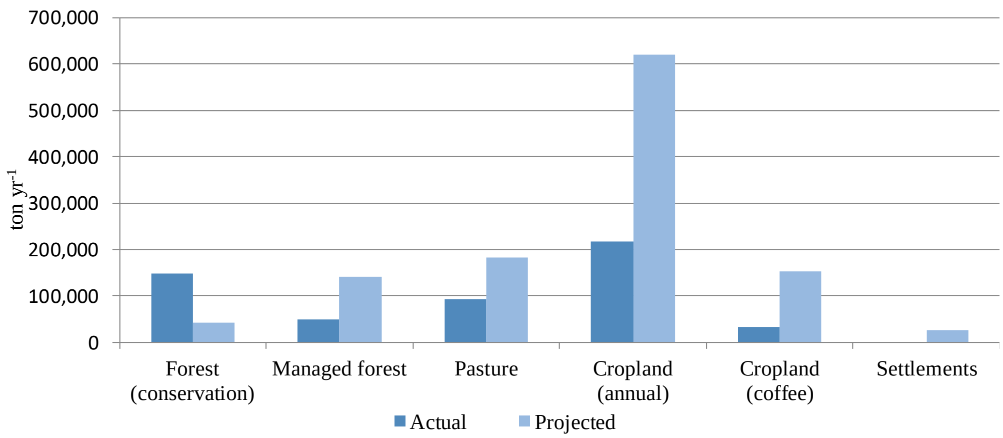
Land use category	Erosion factor (ton $ha^{-1}year^{-1}$)	Soil delivered* (ton $ha^{-1}year^{-1}$)	Soil delivered** (m^3 $ha^{-1}year^{-1}$)
Forest (conservation)	25.11	12.56	16.32
Forest (wood production)	50.23	25.12	32.65
Grassland (pasture)	110.74	55.37	71.98
Cropland (annual)	572.29	286.15	371.99
Cropland (perennial=coffee)	162.10	81.05	105.37
Settlements	162.10	81.05	105.37
Other land	n/a	n/a	n/a

*Erosion factor multiplied by SDR=0.5; **Conversion factor unit of weight to unit of volume 1ton =1.3m^3
Source: Elaborated with values from Santos (1992)

Annual cropland causes the most erosion. Erosion from cropland is almost 23 times the quantity estimated for conserved forest, which is the benchmark cover for comparison. Thus, the land use that is often the most profitable privately also imposes the largest negative externality in terms of soil erosion. The erosion produced by an average coffee plantation, which is assumed the same for settlements, is close to seven times that of the forest land.

These erosion rate values depend on farm management practices. Estimates presented in Table 14 can be considered to be conservative. Volumes of soil delivered during extreme rainfall events, such as hurricanes and tropical storms, are not included. Also, we use a conservative sediment delivered ratio (SDR) equal to 50 percent of soil loss. A value of 53 percent was computed in Puerto Rico for a mountainous area (see Gingold, 2007). If we assume an SDR of 60 percent, estimated soil loss would increase 20 percent. Finally, Figure 6 presents total annual soil loss that would be generated by actual and projected land uses. The change in annual values implies that, if land is converted, erosion from the sample land area would be double the current rates, increasing 404,386 m^3 per year or 46.3 $m^3 ha^{-1} year^{-1}$.

Figure 6. Soil loss from actual and projected area



Source:Source: Computed from Table 9 and 14

We only examined the impact of soil loss that would eventually reach the Tavera dam, reducing its storage capacity. We did not analyze soil productivity loss due to erosion. Now we analyze the economic implications of erosion.

The costs of erosion pertain to two of the three primary uses of water stored in the Tavera dam. Table 15 shows values of a cubic meter of water for farming and for electricity generation. These values as estimated by Santos (1992) were adjusted for inflation. Each cubic meter of the dam's space cost RD$34.60 per year. Although, we did not collect sufficient data to determine the costs of erosion for treating potable water for turbidity, there is evidence to establish some correlations. Forster, Bardos, and Southgate (1987) studied the effect of erosion on treatment cost of water and found that a 10 percent decrease in erosion resulted in a four percent reduction in annual drinking water treatment costs. Appendix 5 presents the water treatment costs of two plants operated by CORAASAN. The correlation between rainfall and costs per year is obvious.

Table 15. Reservoir's space (m^3) value per water use and total

Water use	Reservoir's space value (2018 price)	
	US$ m^{-3} $year^{-1}$	**RD$ $m^{-3}year^{-1}$**
Irrigation/farming	0.3047	15.05
Electricity generation	0.3958	19.55
Drinking/industry	n/e	n/e
Total	**0.7005**	**34.60**

n/e=not estimated; * values adjusted using consumer price index (CPI) 2018/1990; US$=49.40RD$
Source: Santos (1992)

Table 16 depicts the difference in volume of soil delivered and costs by land use with respect to conserved forest. One hectare of managed forest generates increased erosion costs of RD$565.02 per year. The cost of erosion reaches its maximum with annual cropland. Annually, a hectare of cropland costs Dominican society in YNW RD$12,307.56. The cost could be even greater if the control cost of turbidity and other negative effects of erosion were included.

Table 16. Difference in soil delivered and cost by land use compared to conserved forest

Land use category	Difference soil delivered (m^3 $ha^{-1}year^{-1}$)	Social cost	
		(US$ $ha^{-1}year^{-1}$)	**(RD$ $ha^{-1}year^{-1}$)**
Forest (conservation)	0	0.00	0.00
Forest (wood production)	16.328	11.44	565.02
Grassland (pasture)	55.6595	38.99	1,926.05
Cropland (annual)	355.667	249.14	12,307.56
Cropland (perennial=coffee)	89.0435	62.37	3,081.28
Settlements	89.0435	62.37	3,081.28
Other land	n/a	n/a	n/a

Source: Computed from Table 14 and 15.

6.4. Results of total social benefits and private costs

The maximum payment is defined by the total social costs and the minimum payment comes from the private opportunity costs of forest conservation. In other words, high social benefits from forest environmental services mean higher upper bound for payment levels. Results are easily interpreted and lead to direct policy recommendations.

Table 17. Total social cost per land use

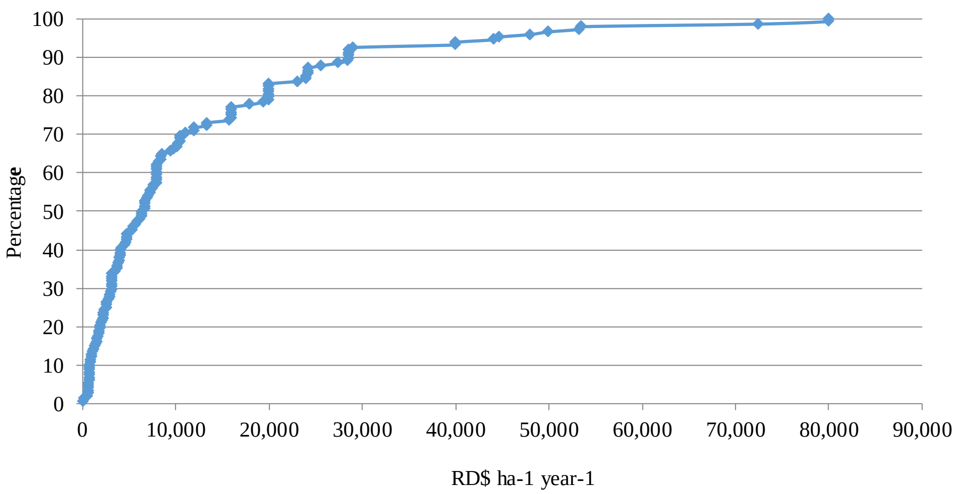
Land use	Social Cost (RD$ $ha^{-1}year^{-1}$)		
	Carbon	Erosion	Total
Forest (conservation)	0.00	0.00	0.00
Forest (wood production)	11,094.42	565.02	11,659.44
Grassland (pasture)	14,089.91	1,926.05	16,015.96
Cropland (annual)	14,089.91	12,307.56	26,397.47
Cropland (perennial=coffee)	2,316.24	3,081.28	5,397.52
Settlements	2,316.24	3,081.28	5,397.52

Source: Computed form Table 12 column B and Table 16

Table 17 presents the social costs of different land uses in terms of carbon and erosion compared to conserved forest. Not surprisingly, annual crop has the highest social cost at RD$26,397.47 per hectare per year. This implies that the highest social value is gained from preventing conserved forest transitions to annual cropland. Or in other words, society should be willing to pay up to this amount to avoid forest conversion to cropland. Based on our estimation, coffee plantations generate a cost for downstream society of almost RD$5,400 $ha^{-1}year^{-1}$. Thus, the upper boundary for social payments to prevent transitions to coffee is much lower.

Figure 8 shows the survey respondents self-reported rental value of forest lands, ranging from RD$111.50 to 80,000.00 $ha^{-1}year^{-1}$. We have assumed that the rental value of forest parcels may represent opportunity costs. Table 4 shows that these values are, on average, below mean incomes from all productive land use activities (forest-wood production, cattle, annual crop and coffee) in the zone. Thus, what share of forest land do the negative social costs of potential conversion exceed to rental value? Figure 8 shows that social costs are greater than rental values for a large share of forest land owners.

Figure 7. Cumulative frequency of annual rental value for one hectare of forest land



Source. Landholders survey, 2018

6.5. Discussion

In summary, the analysis is driven by very different assumptions about the responsiveness of forest plot owners to economic incentives. Results from the analysis of the profitability of alternative land uses with self-reported incomes from alternative uses assumes that forest plot owners will respond to incentives associated with profitability of alternative land uses. However, in the econometric analysis we find that self-reported perceived rental values of forest parcels have no impact (statistically significant) on PES participation. These different results need to be reconciled. First, as explained above, forest land may not have the same characteristics as land currently under productive activities. Thus, one reason for the difference is that self-reported rental values correspond to actual forest lands and are based on projected farming productivity for those land areas. Those areas still conserved as forest are likely to be the least appropriate for farming. Steep slope, accessibility to road, proximity to water source and availability of labor are factors that constrain the income that they can generate. Therefore, the rental income that forest lands can generate would be lower than income for current croplands and pastures. In fact, Jarabacoa and Constanza populations have been established there for a very long time, and farming has been their traditional source of income. Land development has most likely already occurred following a von Thunen process, where the most productive parcels were developed first and marginal agricultural lands remain under forest.

In the past, many forests were degraded or fragmented because rural populations were more disperse. But now, settlements are spatially more concentrated, farmers return home every day, or even enjoy work breaks with the family. Moreover, with the development of agricultural production in greenhouses, farming is more intensive in small low-slope areas near to farmers' houses. All this and other regulatory factors related to forest protection in the study zone explain why income of actual cultivated lands is not directly comparable to potential income from lands remaining as forests.

Second, the lack of significance of the rental value may be influenced by a selection bias in the measurement, where least productive lands have remained in forest. Average self-reported rental value is RD$9,431.87 ha^{-1} $year^{-1}$ for participants while RD$12,937.81 ha^{-1} $year^{-1}$ for non-participants. A difference of around 37 percent higher for non-participants forest lands. Also, the aggregation implied in the rental value makes it a messy indicator of opportunity cost of forest lands. For instance, lands can be appropriated for crops with very diverse profitability. Finally, what landholders perceive as rental value of land can differ from land use income. Given that 31 percent of survey respondents are PES program participants, it is possible they implicitly considered current PES payment level while answering the question about rental value, instead of real income-generating capacity of the land.

On the other hand, values from the reported income analysis should be viewed with caution because they are not strictly representative of farming land populations. Since the survey was targeted at forest landholders, they are not necessarily representative of the farmers' population. In fact, the forest parcels likely belong to better off households within communities. Households in the low end of the income distribution usually have little land or are landless. Low income farmers also likely obtain lower income from the same land use relative to non-poor households. Further, we have analyzed only a small sample for each land use. The sample was especially small for coffee (13) and in livestock (8). Given these caveats there may be bias in both, income and rental value estimates.

Although our results fail to suggest the responsiveness of PES participation to different payment levels, given the previously discussed limitations we believe that a deeper study is needed to evaluate the real effect of opportunity cost on PES enrolment. One methodological choice could be a randomized control trial experiment using different PES payment offers. This approach would help to reduce selection bias.

6.5.1. Enrollment and PES levels

Assuming hypothetically that participation in the PES program can be motivated by payment levels, Table 18 shows minimum willingness to accept, WTA, and social costs (maximum willingness to pay, WTP) derived from Tables 3 and Table 17. The results imply that only grassland, on average, produces a sufficiently high social cost, such that it is economically efficient for society to compensate landowners to avoid conversion of forest to pasture up to above average WTA. For other land uses, environmental services demanders must pay up the social cost values. If it were possible to determine with certainty the transition that resulted from the forest conversion a discriminated payment could be established for each plot. Otherwise, if a fixed payment is established, the value should never exceed the social cost or WTP.

Table 18. Average private cost and social cost per land use

Land use	Average private cost	Social cost
	WTA	**WTP**
Forest (conservation)	0.00	0.00
Forest (wood production)	13,761.00	11,659.44
Grassland (pasture)	14,841.84	16,015.96
Cropland (annual agriculture)	251,970.13	26,397.47
Cropland (perennial=coffee)	17,631.20	5,397.52
Settlements	n/e	5,397.52

Source: Table 4 and 17

Another way to read Table 18 is by taking the ratio of social to average private costs. By doing this, we see that every peso earned in annual cropland generates a cost of ten cents for society. Nevertheless, Figures 3 and 4 demonstrate that a high proportion of coffee plantations and few annual crop plots generate incomes lower than RD$11,000 per hectare yearly; thus in theory, this threshold compensation would be attractive to the share of forest parcels with potential income below that level.

Values in Table 18 and 19 can be very useful for the DR REDD+ benefit-sharing system. While the forest carbon property has not been defined yet, and given the fact that a well-defined land tenancy framework does exist in the country, the distribution of benefits of the REDD+ mechanism can play a key role for the future of forests in YNW. The Emission Reduction Project Idea Note stated that the benefit-sharing system will consider the variety of forest values and stakeholders (ER-PIN, 2015). Results of our study show that if forests have to be conserved, forest owners sacrifice high monetary values.

Our regression results indicate no relationship between landholders' PES enrollment decisions and forest land rental values, but the quantities presented in Table 19, simulating PES payment levels and enrollment, are derived from the recognition of land uses potential rental income. Assuming that a rental land market for productive activities already exists, it would be unreasonable not to take advantage of this information and continue paying a PES rate that is below the income that lands could produce. The objective of having environmental benefits at the minimum cost must be relaxed, given the poverty level and food needs of private providers.

Using the data in Figure 7 we are able to establish some payment levels to guide PES program decisions. Table 19 displays reasonable PES payments based on rental values provided by survey respondents. The rental value was divided into five classes and cumulative frequency (absolute and relative) was computed for observations and surface of each parcel. Data imply that 35 percent of forest lands have rental values below RD$2,500. Actually, the PES program pays RS$2,000 per hectare annually. If PES payment increases by 100 percent, the payment level covers a private rental value of 51 percent of the forest areas. Given that society receives ES regardless of the land use and (for carbon sequestration) regardless of location, a PES level at RD$10,000 would compensate the rental value (indicator of opportunity costs) of 68 percent of the forests and still be below the social costs of all land conversions, except the transition of forest to coffee.

Table 19. Rental value classes and cumulative distribution of forest parcels

PES level			Parcel		Forest land area	
US$	**RD$**	**Δ%**	**Cumulative Frequency**	**Cumulative Frequency (%)**	**Cumulative Frequency (ha)**	**Cumulative Frequency (%)**
< 50	2500		36	24	2,036.02	35
< 75	2800	50	39	26	2,145.27	37
< 100	5000	100	65	43	3,005.39	51
< 200	10000	400	98	65	3,978.59	68
>200	>10000	>400	150	100	5,870.32	100

Source: Landholders survey, 2018: Appendix 4

The choice of PES level will ultimately depend on the need to achieve a certain level of demanded ES. That will require an analysis of distributions of watershed land use. But the current analysis suggests that if land owners do respond to PES incentives, then for the marginal program participant current PES levels may be low relative to the associated social benefits.

All this is complicated by different governmental agencies providing positive incentives to bring land into production. For example, the National Coffee Council (in Spanish CODOCAFE) attempts to increase areas of coffee production by providing technical and financial support to coffee growers. The Ministry of Agriculture does the same to promote cattle and other agricultural food products. The final consequence is that households that own land and usually have available cheap labor, opt to develop their lands. In this scenario, a goal to avoid the harmful effects of erosion and CO_2 emission through forest conservation needs more than a regulation. It requires attaching competitive incentives to ensure the permanence of the forest. One way to do this is through paying the monetary compensation and accompanying it with effective law enforcement.

Finally, given the concurrent PES program goal to contribute to economic development, it would be preferable to pay at least the amount we know landholders could generate using lands for the best available alternative. If this happens, the PES would be contributing with the double objectives of conservation that has social economic value, and also improving the economic welfare of the people in the CYN. Thus, it would be in harmony with the objective for which it was created.

7. CONCLUSIONS

This research project examines the maximum PES level for forest conservation that society can afford in the Yaque del Norte watershed. Social value of the forest was measured in terms of the social cost of carbon retained and the social cost of prevented erosion. Analysis also suggests that enrollment in the PES project may not be primarily motivated by payment levels. In other words, the PES participation decision may be relatively unresponsive to payment levels, as payment flows from land are not driving the participation decision. Factors that appear to be influencing owners' decisions are household characteristics and land characteristics. Thus, there is potential to tailor the PES program based on these characteristics and ecological awareness of landholders.

At the same time the results demonstrate that economic pressure does exist for forest to be converted to other land uses that increase income. Reduction of conserved forest without the PES program intervention is expected to continue. From a sample of 150 parcels (5,870 ha) of forest and coffee, we estimate that 71% could change land use to a more profitable alternative based on households self-reported desires to convert. In the best case, the land will be used for wood production or coffee production, but in the worst case land will change into annual crops and pasture. If projected change occurs, the stock of carbon in the area will be reduced significantly. Potential social damage, due to forest conversion, in terms of carbon sequestration, will cost up to RD$14,090 per hectare yearly.

Natural conditions of the Yaque del Norte watershed and the presence of cropland and pasture facilitate relatively high levels of erosion. Estimates of soil loss delivered to the Tavera dam are projected as high as 372 m^3 $ha^{-1}year^{-1}$ in the most erosive land use (annual crop). The social cost of sediment in terms of water for irrigation and electricity is RD$35 per cubic meter of dam's space. Since erosion is also costly for hillside farmers (see Santos, 1992), for a large number of forest plots it is cost effective for society to avoid forest conversion.

Current PES payment levels are below the opportunity costs of cultivated land and below social gain produced by forest conservation. The implementation of a payment level of around RD$5,000 per hectare per year could be sufficient to compensate forgone income from marginal productive lands. The final decision on a payment level needs to integrate quantity of demanded environmental services. For example, the number of cubic meters of erosion to be annually saved. But the analysis clearly indicates that potential gains to society exist at these payment levels.

Farming activities in the watershed are highly profitable relative to the social externalities that they generate. But, social costs are greater than opportunity costs forgone from forest conservation for a large share of land owners. The opportunity costs of lands in the study area present a large range from an annual average of RD$13,761 per hectare of managed forest for wood production to RD$251,970 for annual crops. Profitability of land uses in Jarabacoa and Constanza explains why it is very difficult to stop deforestation and forest degradation in YNW. It is likely that those results are influenced by the support of public agencies looking at increased social indicators such as food production, and employment levels; consequently forest landholders find many incentives to bring lands into production and sacrifice forests' ES provision. Therefore, society would gain by avoiding forest conversion.

The approach developed in this paper can guide the process of decision making during PES scheme implementation in the DR. Public/social and private benefits assessments should be part of the analysis. A challenge in valuing environmental services is that the value depends on how the present generation values future wealth. Our results show that erosion is not very costly for energy generation in the short term, because the dam has enough space, but in the long run when more and more sediment builds up, the story will be different. Thus, if the present generation places a high price on the future generations' well-being, they will be willing to pay more to forego current erosion.

We assume that when a farmer voluntarily signs a contract to get paid, he will provide the expected level of environmental services from his land. Measurement of the level of contract compliance is beyond the scope of this study. In this research we also do not address the secondary impacts of land conservation on the prices of affected agricultural products nor other broader possible welfare changes in the study area or impacts on the local labor markets. Further research on the value of hydrological environmental services would help identify the effect of erosion on water treatment costs and downstream water availability during dry seasons. Also, a more refined and comprehensive evaluation of the social benefits of forest conservation would help with the debate of the cost effectiveness of PES programs, as would more refined estimates of the opportunity costs associated with alternative land uses.

Policy implications for REDD+

In order to fully implement REDD+ in the Dominican Republic, public and private agencies in the AFOLU sector need to collect specific information on agricultural production in order to estimate the amount of carbon released. This information may include: area and yield per crop, area converted from forest to cropping or pasture, among others.

Our results can help guide the future implementation of REDD+ in the DR. Only 23 percent of the landholders in the survey have a title of their forest land. Nevertheless, they did not report any property right issue. This lack of secure tenure can be a barrier to transfer benefits under the REDD+ mechanism, even if landholders have total control of land access. The current

PES program pays forest holders with a possession certificate. But, would it be sufficient for REDD+?

Annual cropping systems constitute primary drivers of deforestation. The aggregation in the survey data does not allow for precisely ranking specific crops. But the data does provide evidence that vegetable pear is the crop with the highest number of producers. And since vegetable pear can be cultivated as individual crop in hillside, it is one of the crops that need to be regulated as part of policies to reduced deforestation in Yaque del Norte.

Expansion of effectively regulated forest management can be beneficial for soil and carbon retention in YNW in comparison with annual crops and pasture. Results of most profitable uses of forest parcels and social costs of alternative uses suggest that coffee and managed forest produce relatively the lower social costs. However, given the volatility in coffee markets, a policy to foster coffee expansion needs to be explored with caution.

Results suggest that landholders value environmental amenities from forest conservation. Therefore environmental education should be included in the strategy to increase conserved forest in the zone and consequently it social benefits.

Policy implications of our research results are largely consistent with policy opinions identified in the preparation process of REDD+ in the DR. The results support REDD+ measures of command and control (regulation enforcement) and education. The former includes land tenure, forest management, and territorial land planning among others. The latter may focus on education and promotion of nature value for society. The results also identify clear minimum PES payment levels to compensation for environmental externalities that are higher than current payment levels, suggesting that more generous incentives for forest conservation thru PES payments will generate broad social benefits.

APPENDICES

Appendix 1. Villages within the project study area with payment offer

Villages	Number of households (hh)	Population	Average persons per hh	% Households with low socio-economic status	% Households with cultived land	% 15+ can read and write	% Main occupation agriculture or related
El Río	300	1228	4.1	23.0	12.3	83.3	14.1
Las Palmas Arriba	140	558	4.0	46.4	13.6	72.3	40.3
Arroyo Frío	136	505	3.7	21.3	8.8	83.0	15.6
El Arroyazo (Arroyo del Toro)	126	448	3.6	61.1	20.6	77.1	25.7
La Pelada	103	332	3.2	74.8	7.8	53.5	16.2
La Descubierta	80	287	3.6	43.8	28.8	77.4	23.3
El Cercado	77	426	5.5	48.1	15.6	86.3	20.7
Paragua	46	165	3.6	84.8	23.9	35.8	48.1
Las Palmas o las Palomas	32	116	3.6	25.0	18.8	65.9	34.0
Paso Bajito	108	397	3.7	80.6	34.3	68.8	53.1
La Guázara	85	344	4.0	30.6	4.7	85.0	32.4
La Pista	84	270	3.2	65.5	27.4	83.0	40.1
Arroyo la Pista	49	212	4.3	53.1	32.7	72.9	41.4
Masipedro	44	162	3.7	56.8	56.8	80.3	17.6
Arroyo la Vaca	39	143	3.7	56.4	28.2	71.3	18.8
La Travesía del Mulo	28	89	3.2	89.3	21.4	63.8	69.8
Ciénaga	70	255	3.6	62.9	17.1	59.4	71.4
Los Dajaos	66	249	3.8	72.7	21.2	73.8	21.1
Mata de Café	67	251	3.7	88.1	37.3	58.1	55.8
El Arraigan	56	217	3.9	71.4	42.9	72.3	50.6
Paso de la Perra	29	92	3.2	82.8	27.6	52.9	16.7
El Dulce o Arroyo Dulce	28	100	3.6	100.0	46.4	44.6	67.6
La Angostura	26	81	3.1	61.5	0.0	72.6	5.0
Los Marranitos	18	71	3.9	55.6	22.2	71.7	4.3
La Jagua	54	215	4.0	77.8	11.1	69.5	8.1
La Yautía	107	370	3.5	35.5	22.4	78.8	28.2
La Lomita	38	99	2.6	102.6	28.9	33.7	77.3
Mata Cadillo	43	130	3.0	51.2	18.6	81.8	25.6
Arroyo Verraco	7	28	4.0	57.1	57.1	82.6	38.5
Los Pasos	29	107	3.7	86.2	41.4	80.0	61.3
Las Calabazas	11	37	3.4	100.0	9.1	50.0	69.2
Los Ranchitos	12	47	3.9	16.7	0.0	58.6	45.5
Los Corozos	52	185	3.6	48.1	11.5	63.4	30.6
La Cienaguita	26	98	3.8	96.2	38.5	45.3	33.3

Villages	Number of households (hh)	Population	Average persons per hh	% Households with low socio-economic status	% Households with cultived land	% 15+ can read and write	% Main occupation agriculture or related
Pinar del Yaque (La Piña)	37	113	3.1	21.6	8.1	81.4	21.7
La Frisa	11	45	4.1	90.9	63.6	54.5	4.8
Arroyo Ancho	62	181	2.9	79.0	27.4	73.0	18.0
La Pocilga	37	113	3.1	62.2	27.0	85.5	31.0
Mata de Plátano	27	87	3.2	63.0	3.7	91.7	22.5
La Cigua	35	128	3.7	14.3	2.9	92.5	4.0
Boca de los Ríos	27	107	4.0	66.7	0.0	94.0	36.0
Los Calabazos	31	101	3.3	77.4	22.6	78.6	33.3
La Cortina	28	96	3.4	57.1	32.1	75.0	48.9
El Bolo o la Pelua	33	100	3.0	100.0	30.3	64.6	62.2
El Manguito o Zumbador	16	89	5.6	106.3	37.5	59.7	8.0
Piedra Llana	21	63	3.0	104.8	33.3	77.3	56.3
Mata de Limón	115	409	3.6	45.2	18.3	61.4	37.0
Joya de Ramón	37	134	3.6	59.5	21.6	59.2	26.2
Los Tablones	10	33	3.3	110.0	0.0	60.0	81.3
Pino del Rayo	47	161	3.4	48.9	31.9	68.9	37.1
Arroyo del Rancho	36	126	3.5	75.0	5.6	60.9	42.6
La Joya o la Joya del Tetero	13	37	2.8	30.8	23.1	89.3	70.0
La Redonda (Tierra Colorada, El Abanico)	48	172	3.6	39.6	47.9	73.4	37.2
Pajarito	47	153	3.3	68.1	29.8	89.8	17.8
Total	**2,934**	**10,762**					

Source: ONE, National Census of Population a Housing 2010

Appendix 2. Values used by Blas Santos (1992) for erosion estimates

A. USLE factors per land use

Land use	R	K	Length	Slope	LS	C	P
Unmanged forest	1208.01	0.64	45	50	21.66	0.0015	1
Managed forest	1208.01	0.64	45	50	21.66	0.003	1
Tradictional conuco	866.01	0.25	45.39	25.76	7.55	0.35	1
Coffee	1208.01	0.36	50.81	46.86	20.88	0.0499	0.5074
Pasture	866.01	0.44	53.67	23.22	6.92	0.042	1

Sources: R, SEA 1982; K, LS, Plan Sierra Survey Data, 1990; C, Plan Sierra Survey Data, and SEA 1981; P, SEA 1981.

B. Other parameter values and sources

Parameter/factor	From	To	Value
Conversion factor units of weight to units of volume	ton	m3	1.3
Sediment Delivery Ratio (SDR)			0.5

Appendix 3. Landholders survey questionnaire

PES Yaque del Norte DR
Survey questionnaire 2018
Cover page

INTERVIWER: *Please locate the person (s) in the household that makes the decisions on households land uses. Write down that person's role and name (we will refer to that person as farmhead). If more than one person takes part on household's land use decisions, answer personal questions for the one with greatest responsibility.*

Husband _____ Wife _____ Son _____Daughter _____Other (specify)_______________________

Farmhead's name_______________________________________Cellphone:______________________________

INTERVIEWER: PLEASE READ DE FOLLOWING STATEMENT TO THE FARMHEAD:

We are conducting a survey on the characteristics of forest parcels landholders located in the area of influence of the PSA-CYN. This survey project involves Virginia Tech University in the United States and PSA-CYN in Dominican Republic. The estimated response time for this survey is 30 minutes. Responding to the questions on this survey is voluntary. If you agree to respond, your answers will remain confidential.

Do you consent to response?

_____________ a) No. *Thank the person and stop interview*
______________b) Yes. *Thank the person for agreeing to participate and go on*

Please indicate if you would like to receive information of the research results when available and desired way:

____ a) Receive a printed summary
____ b) Participate in a presentation.

1. Municipality name	
2. Community name	
3. Interview date	[__|__][__|__][__|__][__|__] dd/mm/yyyy
4. Time interview started	[__|__][__|__] hh mm
5. Time interview finished	[__|__][__|__] hh mm
6. Result *	[__]
*Result 1 = complete, 2 = not complete, 3 = rejection, 99 = other (specify)______________________________	

7. Interviewer's Name:____
8. Interviewer's Institution:____
9. Interviewer's comments:

Date (dd-mm-yy):_______________________

I. Household/Farmhead attributes

1. Gender (mark):
   ______________a) Male
   ______________b) Female
2. What is your age? _________ years
3. What is your primary occupation?
   ______________a) Agriculture (any type)
   ______________b) Wage job
   ______________c) Business
   ______________z) Other (please specify)____________________________________
4. What is the highest grade/year in school you have completed? _________________
5. What is your marital status?
   ______________a) Married (legal or not)
   ______________b) Single/never married
   ______________c) Widow/Widower
   ______________d) Divorce/Separated
   ______________z) Other (please specify)____________________________________
6. What is the size of the family in this household? _______________
7. How many people of this household work in farming/agriculture? _______________
8. Is farming the main income source of this household? ___________
9. Which of the following assets do you own or have access to? *(please check all that apply and quantity*)

Assets	Own	Borrow	Rent in
a) Knapsack sprayer			
b) Water pump			
d) Motorcycle			
e) Pickup			
f) Truck			
g) Horse/mule			
h) Oxen			
i) Tractor			
z) Other (please specify)_____			

10. Are you or any one of this household member of a community/farmers' organizations? ___________
11. Are you aware of the Payment for Environmental Services (PES) program for Yaque del Norte river?_________
12. Are you or your household receiving payments through a PES contract?______how much RD$/year?________
13. How did you become aware of the Payment for Environmental Services program?
    _____________ a) Via a PSA-CYN technician in promotion event
    ______________b) Via local organization
    ______________c) Via a neighbor/friend
    ______________z) Other (please specify)____________________________________

14. The money you receive as payment for PSA, is it used mainly for?
_____________ a) House improvements
_____________ b) Children education
______________c) Farm improvements
______________d) Family food
______________z) Other (please specify)____________________________________

15. Does this household receive social assistance through the "solidaridad" card? _____________

II. Biophysical attributes of forest lands

16. Please specify the area of land your household has according to the type of use, and how much net income you made last year (March 2017 to February 2018) from each land use. (*Take note on reported units and convert to hectare*).
______________a) Total household's lands
______________b) Forest land ______________RD$/annually
______________c) Coffee land ______________RD$/annually
______________d) Livestock land _____________ RD$/annually
______________e) Agriculture _____________ RD$/annually
______________z) Other (please specify)____________________________________

17. How many forest parcels/plots does this household have?___________

18. Which is the area of each parcel? 1)_______ 2)________ 3)_________, ….n parcels.
(Please take note numerating each parcel in the order mentioned with its respective area)

(Now, ask the respondent to choose one number between 1 and n. Then response questions from 19 to 29 only for the forest land that correspond to the chosen number)

19. How far is your **forest land** from …

	Km	Minutes	Transp. Mean*
a). the nearest road?			
b). your home?			
c). the nearest urban market?			

**Transportation means: on foot, by horse, by car, by motorcycle.*

20. Approximate slope on the **forest land?**_______________(%)
(Ask respondent to describe location of the parcel, then approximate the slope using the cartographic map provided)

21. Geographic location of this f**orest land** (*UTM from GPS or map*) X;_________________ Y:________________

22. How many water bodies are within your f**orest land**?_________________

23. What type of ownership document do you have of your **forest land**?
______________a) Title
______________b) Notarized document (rent in, buy,..)
______________c) Possession certificate
______________z) None document

24. Is your forest land free from property rights conflicts?________________

25. What is currently your **forest land** use for? _________________
______________a) Ecotourism

______________b) Food source for animals
______________c) Source of fence posts and firewood
______________d) Source of wood
______________z) Other (please specify)_______________________________________

26. Which do you think is the most profitable productive farming activity in the **forest lands**?
_______________a) Agriculture (please specify crops):____
_______________b) Logging
_______________c) Cattle
_______________z) Other (please specify)_____________________________________

27. How much do you think your **forest land parcel** is worth? ________________RD$

28. Are you receiving any payment from your **forest land parcel** different from PES? _________RD$/month/year

29. How much do you think is the annual value of your **forest land parcel** for rent out? _______________RD$

III. Attitude of landholders on environmental conservation (6 Items form Revised New Environmental Paradigm – NEP, Dunlap et al. 2000)*					
30. Listed below are statements about the relationship between humans and the environment. For each one, please indicate whether you:	1. Strongly agree	2. Agree	3. Unsure	4. Disagree	5. Strongly disagree
1. Humans have the right to modify the natural environment to suit their needs.					
2. Humans are severely abusing the environment.					
3. Plants and animals have as much right as humans to exist.					
4. The balance of nature is strong enough to cope with the impacts of modern industrial nations.					
5. Humans were meant to rule over the rest of nature.					
6. The balance of nature is very delicate and easily upset.					

*Note: *Agreement with the odd–numbered items and disagreement with the even–numbered items indicate pro–NEP responses.*

PES Yaque del Norte DR
Survey questionnaire 2018

Annex1. Income per productive activity in the last year (March 2017 to February 2018)

*Crop:_______________________ Area:________ How long has been this crop in this plot?__________

Activity/concept	Unit	Quantity	Unit value RD$	Total value RD$
Input costs				
Plant/seed purchase				
Fertilizer purchase				
Herbicide purchase				
Pesticide/Insecticide purchase				
Subtotal Input costs				
Revenue/Benefits				
Total yield**				
Subtotal Input revenue				
Total net income				

*If more than one crop in the same land on the same year, please fill out a separated spreadsheet.

** If several prices for different product grade, recall all or approximate an average value considering volume in the different grades.

……

*Crop:_______________________ Area:________ How long has been this crop in this plot?__________

Activity/concept	Unit	Quantity	Unit value RD$	Total value RD$
Input costs				
Plant/seed purchase				
Fertilizer purchase				
Herbicide purchase				
Pesticide/Insecticide purchase				
Subtotal Input costs				
Revenue/Benefits				
Total yield**				
Subtotal Input revenue				
Total net income				

*If more than one crop in the same land on the same year, please fill out a separated spreadsheet.

** If several prices for different product grade, recall all or approximate an average value considering volume in the different grades.

Appendix 4. A. Observations grouped in actual land use (initial area) (ha)

Obs	Forest Conservation	Managed Forest	Cattle	Agriculture	Coffee	Settlements (summer houses)	Other land
1	0.00	156.25	0.30	0.13	0.13	**0.00**	0.25
2	1.00	310.00	0.50	0.19	0.25		0.50
3	1.00	500.00	0.50	0.19	0.31		1.25
4	1.00	**966.25**	0.75	0.25	0.31		2.18
5	1.00		1.25	0.30	0.38		4.38
6	1.00		2.81	0.30	0.44		6.25
7	1.00		3.10	0.31	0.50		6.50
8	1.00		3.12	0.31	0.50		10.63
9	1.00		3.13	0.31	0.56		25.00
10	1.25		3.13	0.38	0.63		68.75
11	1.25		3.75	0.38	0.69		137.50
12	1.87		3.75	0.44	0.75		155.00
13	1.87		4.38	0.44	0.93		**418.18**
14	1.88		5.00	0.44	0.94		
15	2.19		5.13	0.44	0.94		
16	2.50		6.25	0.44	1.25		
17	2.50		6.25	0.44	1.25		
18	2.50		6.25	0.44	1.25		
19	2.50		8.75	0.50	1.25		
20	3.13		9.38	0.50	1.25		
21	3.13		12.50	0.50	1.50		
22	3.13		12.50	0.50	1.50		
23	3.13		12.50	0.50	1.56		
24	3.13		12.50	0.63	1.60		
25	3.16		18.75	0.63	1.86		
26	3.75		21.00	0.63	1.88		
27	4.25		21.90	0.63	1.88		
28	4.38		31.25	0.63	1.88		
29	4.63		34.38	0.63	1.90		
30	5.00		37.50	0.63	2.00		
31	5.00		43.75	0.75	2.19		
32	5.00		62.50	0.75	2.50		
33	5.00		156.25	0.75	2.50		
34	6.25		281.25	0.88	2.50		
35	6.25		**835.99**	0.94	3.13		
36	6.25			0.94	3.13		

Obs	Forest Conservation	Managed Forest	Cattle	Agriculture	Coffee	Settlements (summer houses)	Other land
37	6.25			0.94	3.75		
38	6.25			1.00	3.75		
39	6.25			1.00	3.75		
40	6.25			1.00	5.00		
41	6.25			1.00	6.25		
42	6.75			1.13	6.25		
43	6.88			1.25	6.25		
44	7.06			1.25	6.25		
45	7.19			1.25	8.30		
46	7.50			1.25	9.40		
47	7.50			1.25	12.50		
48	7.81			1.25	14.00		
49	7.86			1.25	18.75		
50	8.20			1.30	50.00		
51	8.75			1.31	**202.19**		
52	8.75			1.38			
53	9.38			1.50			
54	10.00			1.50			
55	10.00			1.56			
56	10.31			1.60			
57	10.31			1.60			
58	10.41			1.86			
59	10.63			1.87			
60	11.19			1.88			
61	12.50			1.88			
62	12.50			1.88			
63	12.50			1.88			
64	12.50			1.88			
65	12.50			1.88			
66	12.50			1.88			
67	12.50			1.88			
68	12.50			1.88			
69	12.51			1.90			
70	14.69			2.00			
71	14.90			2.19			
72	15.00			2.19			
73	15.63			2.19			

Obs	Forest Conservation	Managed Forest	Cattle	Agriculture	Coffee	Settlements (summer houses)	Other land
74	15.63			2.50			
75	15.63			2.50			
76	16.00			2.50			
77	16.25			2.50			
78	16.88			2.50			
79	17.63			2.50			
80	17.75			2.75			
81	18.75			3.13			
82	18.75			3.13			
83	18.75			3.13			
84	18.75			3.13			
85	22.66			3.25			
86	24.93			3.44			
87	25.00			3.44			
88	25.00			3.44			
89	25.50			3.75			
90	25.68			3.75			
91	28.00			3.75			
92	28.00			3.75			
93	28.13			3.75			
94	28.13			3.75			
95	31.25			3.94			
96	31.25			4.00			
97	31.25			4.38			
98	32.19			4.69			
99	32.75			5.50			
100	34.38			6.25			
101	40.13			6.25			
102	40.63			6.25			
103	41.06			6.25			
104	41.12			6.26			
105	43.75			7.50			
106	43.75			7.50			
107	45.00			10.63			
108	46.87			12.50			
109	50.00			14.00			
110	54.31			16.94			

Obs	Forest Conservation	Managed Forest	Cattle	Agriculture	Coffee	Settlements (summer houses)	Other land
111	56.25			18.75			
112	56.25			48.13			
113	62.50			50.00			
114	62.50			**381.67**			
115	62.50						
116	62.50						
117	62.50						
118	65.63						
119	67.19						
120	75.00						
121	78.46						
122	78.50						
123	85.75						
124	87.50						
125	89.69						
126	93.75						
127	94.75						
128	95.25						
129	129.50						
130	137.50						
131	146.00						
132	151.00						
133	151.87						
134	155.00						
135	156.24						
136	160.00						
137	187.50						
138	187.50						
139	187.50						
140	296.88						
141	297.00						
142	312.63						
143	375.00						
	5,932.33						

Source: Landholders survey 2018

Appendix 4. B. Observations grouped in potential conversions (final area) (ha)

Obs	Forest Conservation	Managed forest	Cattle	Agriculture	Coffee	Settlements (summer houses)
1	1.00	1.87	1.00	1.50	1.00	3.13
2	1.00	1.87	1.00	2.50	1.00	12.50
3	1.00	2.19	2.50	5.00	1.00	46.87
4	4.25	2.50	2.50	6.25	1.25	93.75
5	4.38	3.13	3.13	8.75	1.25	
6	5.75	3.75	7.81	10.00	1.88	
7	7.06	5.00	10.41	15.63	1.88	
8	8.20	6.25	12.50	28.13	3.13	
9	9.38	6.25	12.50	43.75	3.13	
10	10.31	6.25	12.50	87.50	3.16	
11	10.56	6.88	18.75	146.00	3.50	
12	15.00	7.86	25.00	160.00	3.75	
13	22.66	8.75	28.13	187.50	5.00	
14	25.00	10.63	46.69		5.00	
15	43.75	12.50	62.50		5.50	
16	67.00	12.50	62.50		6.25	
17	94.75	14.69	65.37		6.25	
18	312.63	15.63	67.19		6.25	
19		15.63	75.35		6.25	
20		16.00	297.00		6.25	
21		16.25			6.25	
22		16.88			6.75	
23		20.25			7.19	
24		25.00			7.50	
25		28.00			7.50	
26		29.00			9.38	
27		30.00			11.19	
28		34.38			12.50	
29		36.25			12.50	
30		45.00			12.50	
31		56.25			12.50	
32		56.25			15.00	
33		56.25			18.75	
34		62.50			18.75	
35		62.50			18.75	
36		62.50			21.50	

Obs	Forest Conservation	Managed forest	Cattle	Agriculture	Coffee	Settlements (summer houses)
37		89.69			25.68	
38		92.50			31.25	
39		151.00			31.25	
40		151.87			31.25	
41		187.50			32.19	
42		375.00			40.63	
43		453.13			41.12	
44		500.00			75.00	
45					156.25	
	643.67	**2,798.05**	**814.32**	**702.50**	**735.79**	**156.25**

Note: Forest land that we did not asked for change 1,049.505 ha
Source: Landholders survey 2018

Appendix 5. Treatment cost of drinking water and rainfall 2014-2017

		PLANT 25 MGD			PLANT 10 MGD				
Year	**Rainfall (mm)**	**Treated water (m^3)**	**Cost (RD$)**	**Average RD$/$m^3$**	**Treated water (m^3)**	**Cost (RD$)**	**Average RD$/$m^3$**	**Water consumption (m^3)**	**Total annual Cost RD$**
2013	1395.5								
2014	1514.2	25,579,485	72,954,421	2.85	5,675,246	26,591,424	4.69	32,508,809	99,545,845
2015	1080.0	23,895,648	65,667,894	2.75	4,718,689	24,448,566	5.18		90,116,460
2016	1928.7	23,249,597	78,744,295	3.39	5,222,817	29,319,962	5.61	29,170,594	108,064,257
2017	1879.1	18,292,608	77,881,369	4.26	10,637,568	28,553,429	2.68		106,434,799

Source: water treatment cost, CORAASAN; rainfall, ONAMET Jarabacoa Estation.

Prices adjusted for inflation

*In 2017 treatment facility (plant 10NGD) was improved.

year	CPI
2014	118.13
2015	118.86
2016	121.13
2017	124.22
2018	129.36

Appendix 6. Rental value for parcel from survey of landholders

Obs	Parcel (ha)	Rental value (RD$/ha/year)	Obs	Parcel (ha)	Rental value (RD$/ha/year)	Obs	Parcel (ha)	Rental value (RD$/ha/year)
1	89.69	111.50	51	12.50	3,556.67	101	453.13	10,491.95
2	94.75	211.08	52	3.75	3,733.33	102	7.06	10,491.95
3	56.25	533.33	53	12.50	3,750.00	103	1.00	10,504.20
4	151.87	658.46	54	12.50	3,840.00	104	500.00	11,102.86
5	16.88	710.90	55	5.00	4,000.00	105	2.50	12,000.00
6	56.25	711.11	56	12.50	4,000.00	106	1.00	12,000.00
7	18.75	729.57	57	4.38	4,088.89	107	15.00	13,333.33
8	41.12	729.57	58	6.25	4,088.89	108	21.50	13,333.33
9	12.50	800.00	59	5.00	4,088.89	109	3.16	15,822.78
10	31.25	800.00	60	7.50	4,266.67	110	1.88	15,957.45
11	12.50	800.00	61	43.75	4,571.43	111	3.13	15,974.44
12	62.50	800.00	62	10.56	4,733.73	112	1.25	16,000.00
13	87.50	800.00	63	3.13	4,792.33	113	6.25	16,000.00
14	15.63	800.00	64	6.75	4,800.00	114	6.25	16,000.00
15	12.50	800.00	65	6.25	4,800.00	115	67.00	18,000.00
16	65.37	917.85	66	7.81	5,120.00	116	10.31	19,393.94
17	62.50	960.00	67	18.75	5,333.33	117	1.00	20,000.00
18	9.38	1,066.67	68	5.50	5,454.55	118	1.00	20,000.00
19	18.75	1,066.67	69	8.75	5,714.29	119	2.50	20,000.00
20	56.25	1,155.56	70	12.50	6,000.00	120	5.00	20,000.00
21	160.00	1,250.00	71	32.19	6,213.11	121	1.00	20,000.00
22	146.00	1,328.77	72	15.63	6,397.95	122	5.00	20,000.00
23	156.25	1,536.00	73	6.25	6,400.00	123	1.00	20,000.00
24	1.00	1,653.33	74	62.50	6,400.00	124	10.41	23,049.22
25	151.00	1,655.63	75	297.00	6,734.01	125	12.50	24,000.00
26	46.87	1,706.85	76	15.00	6,768.03	126	62.50	24,000.00
27	28.00	1,785.71	77	1.25	6,768.03	127	1.87	24,213.00
28	25.00	1,800.00	78	8.30	6,768.03	128	375.00	24,213.00
29	20.25	1,975.31	79	7.19	6,956.52	129	67.19	24,213.00
30	75.35	2,000.00	80	28.13	7,111.11	130	9.38	25,600.00
31	10.00	2,040.00	81	6.88	7,272.73	131	2.00	27,500.00
32	16.25	2,153.85	82	8.20	7,317.07	132	28.13	28,444.44
33	12.50	2,240.00	83	16.00	7,500.00	133	25.00	28,568.89
34	2.19	2,283.11	84	15.63	7,680.00	134	6.25	28,568.89
35	25.68	2,336.45	85	31.25	8,000.00	135	10.63	28,568.89
36	187.50	2,400.00	86	6.25	8,000.00	136	25.00	28,568.89

PES YAQUE DEL NORTE DR

Obs	Parcel (ha)	Rental value (RD$/ha/year)	Obs	Parcel (ha)	Rental value (RD$/ha/year)	Obs	Parcel (ha)	Rental value (RD$/ha/year)
37	75.00	2,666.67	87	2.50	8,000.00	137	34.38	29,090.91
38	30.00	2,666.67	88	7.50	8,000.00	138	6.25	40,000.00
39	4.25	2,678.97	89	187.50	8,000.00	139	1.25	40,000.00
40	45.00	2,888.89	90	18.75	8,000.00	140	22.66	44,130.63
41	312.63	3,000.00	91	6.25	8,000.00	141	11.19	44,692.74
42	92.50	3,010.14	92	3.13	8,000.00	142	2.50	48,000.00
43	62.50	3,116.19	93	36.25	8,275.86	143	1.00	50,000.00
44	7.86	3,180.66	94	43.75	8,470.00	144	1.50	53,333.33
45	6.25	3,200.00	95	3.75	8,470.00	145	1.87	53,475.94
46	6.25	3,200.00	96	3.50	8,571.43	146	0.69	72,463.77
47	31.25	3,200.00	97	8.75	9,478.26	147	1.88	80,000.00
48	3.13	3,200.00	98	40.63	9,846.15	148	1.25	80,000.00
49	93.75	3,200.00	99	14.69	10,212.77	149	3.13	
50	46.69	3,212.85	100	29.00	10,344.83	150	5.75	

Source: Landholders survey 2018.

REFERENCES

AIRD. (n/d). Senadores prueban proyecto de ley sobre pago por servicios ambientales. Retrieved from http://www.portalindustrial.net/index.php/novedades/alertas/117-senadores-prueban-proyecto-de-ley-sobre-pago-por-servicios-ambientales

Alix-Gracia, J., De Janvry, A., & Sadoulet, E. (2008). The role of deforestation risk and calibrated compensation in designing payments for environmental services. *Environment and Development Economics, 13*, 375-394. doi:0.1017/S1355770X08004336

Altrieth, B., Benoit, P., & Franco, F. (2002). Determinacion de los costos-beneficios de cultivos tradicionales en la Cuenca Alta del Rio Yaque del Norte. In: Proyecto Cuenca Alta Rio Yaque del Norte (PROCARYN). Jarabacoa, Republica Dominicana.

Bergstrom, J. C., & Randall, A. (2016). *Resource economics: An economic aproach to natural resouce and environmental policy*. MA, USA: Edward Elgar Publishing, Inc.

Boardman, J. (2006). Soil erosion science: Reflections on the limitations of current approaches. *Catena, 68*(2-3), 73-86. doi:10.1016/j.catena.2006.03.007

Borrego, A., & Skutsch, M. (2014). Estimating the opportunity costs of activities that cause degradation in tropical dry forest: Implications for REDD. *Ecological Economics, 101*, 1-9. doi:10.1016/j.ecolecon.2014.02.005

Bueno, S. (2014). *Medición y predicción de la biomasa y el contenido de carbono de árboles individuales y rodales naturales de Pinus occidentalis en la provincia de Santiago, República Dominicana*.

CCJ. (2006). Estudio de linea base del cafe en Jarabacoa In. Jarabacoa. Republica Dominicana: Cluster de Café de Jarabacoa con apoyo de USAIDChemonics Programa de Competitividad y Políticas CNC/BID.

CEPAL. (2002). Crisis del café impacta a las economías latinoamericanas. Retrieved from CEPAL website:https://www.cepal.org/cgi-bin/getProd.asp?xml=/prensa/noticias/comunicados/7/9727/P9727.xml&xsl=/prensa/tpl/p6f.xsl

Chacón, P., Leblanc, H. A., & Russo, R. O. (2007). Fijación de carbono en un bosque secundario de la región tropical húmeda de Costa Rica. *Tierra Tropical, 3*(1), 39-49.

CNE/EGEHID. (2009). *Estudio para determinar el costo de producción de la hidroelectricidad de la Empresa de Generación Hidroeléctrica Dominicana (EGEHID)*. Comisión Nacional de Energía (CNE) and Empresa de Generación Hidroeléctrica Dominicana (EGEHID). Santo Domingo, Dominican Republic.

Ley General sobre Medio Ambiente y Recursos Naturales de la Republica Dominicana, (2000).

Ley Orgánica de la Estrategia Nacional de Desarrollo de la República Dominicana 2030, (2012).

Diaz, R. L., & Montero, T. (2010). *Determinación de incremento en pino criollo (Pinus occidentalis) en 27 parcelas en los municipios Jarabacoa y Constanza, durante el período 2008-2009* (Ingenieria), Universidad Agroforestal Fernando Arturo de Meriño (UAFAM), Jarabacoa, Republica Dominicana.

Dunlap, R. E., Van Liere, K. D., Mertig, A. G., & Jones, R. E. (2000). Measuring endorsement of the new ecological paradigm: A revised NEP scale. *Journal of social issues, 56*(3), 425–442.

ER-PIN. (2015). *Emission reduction program of the Dominican Republic: Contributions to sustainable livelihoods of rural communities and carbon enhancements*. República Dominicana Retrieved from https://www.forestcarbonpartnership.org/sites/fcp/files/2015/September/Dominican%20Republic%20ER-PIN%20Final.pdf.

Espinola-Arredondo, A. (2008). Green auctions: A biodiversity study of mechanism design with externalities. *Ecological Economics, 67*(2), 175-183. doi:10.1016/j.ecolecon.2008.04.014

FAO. (2008). *Forest and water: A thematic study prepared in the framework of the Global Forest Resouces Assessment 2005*. Rome: Food and Agriculture Organization of the United Nations

Ferraro, P. J. (2007). Asymmetric information and contract design for payments for environmental services. *Ecological Economics, 65*(2008), 810-821. doi:10.1016/j.ecolecon.2007.07.029

Figueroa, E., & Pasten, R. (2014). Economically valuing nature resources to promote conservation: An empirical application to Chile's national system of protected areas. *Papers in Regional Science, 93*(4), 865-888. doi:10.1111/pirs.12036

Flores, N. L. (2016). *Impact assessment of natural resource management policy research: A case study of the contribution of the Sustainable Wetlands Adaptation and Mitigation Project to the effectiveness of the Indonesian Forest Moratorium.* (Master of Science), Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Forster, D. L., Bardos, C. P., & Southgate, D. D. (1987). Soil erosion and water treatment costs. *Journal of Soil and Water Conservation, 42*(5), 349-352.

Gangotena, J. (2008). Implementacion del Proyecto Pago por Servicios Ambientales
Informe del Proceso periodo mayo-diciembre 2008. 1-126.

Gingold, E. A. (2007). *Valuing water and sedimient tradeoffs between forest and pasture in montane tropical environment in Puerto Rico.* (Master), University of Pensylvania Pennsylvania

Hejnowicz, A. P., Raffaelli, D. G., Rudd, M. A., & White, P. C. L. (2014). Evaluating the outcomes of payments for ecosystem services programmes using a capital asset framework. *Ecosystem Services, 9*, 83-97. doi:10.1016/j.ecoser.2014.05.001

Ickowitz, A., Sills, E., & de Sassi, C. (2017). Estimating smallholder opportunity costs of REDD+: A pantropical analysis from households to carbon and back. *World Development, 95*(Supplement C), 15-26. doi:https://doi.org/10.1016/j.worlddev.2017.02.022

IDIAF. (2010). Valoración de los servicios ambientales hidricos, potencial y fijacion de carbono del bosque cafetalero en Soliman y Juncalito. In. Republica Dominicana: Instituto Dominicano de Investigaciones Agropecuarias y Forestales.

IPCC. (2006). 2006 IPCC guidelines for national greenhouse gas inventories. In *Agriculture, Forestry and Other Land Use* (Vol. 4). Japan: IGES.

IWG. (2016). Technical update on the social cost of carbon for regulatory impact analysis-under executive order 12866. *Interagency Working Group on Social Cost of Carbon, United States Government*.

Field Code Changed

Kemkes, R. J., Farley, J., & Koliba, C. J. (2010). Determining when payments are an effective policy approach to ecosystem service provision. *Ecological Economics, 69*(11), 2069-2074. doi:10.1016/j.ecolecon.2009.11.032

Kinnell, P. I. A. (2010). Event soil loss, runoff and the Universal Soil Loss Equation family of models: A review. *Journal of Hydrology, 385*(1-4), 384-397. doi:10.1016/j.jhydrol.2010.01.024

Kongsager, R., Napier, J., & Mertz, O. (2012). The carbon sequestration potential of tree crop plantations. *Mitigation and Adaptation Strategies for Global Change, 18*(8), 1197-1213. doi:10.1007/s11027-012-9417-z

Le Velly, G., & Dutilly, C. (2016). Evaluating payments for environmental services: Methodological challenges. *PLoS One, 11*(2), e0149374. doi:10.1371/journal.pone.0149374

Ma, S., Swinton, S. M., Lupi, F., & Jolejole-Foreman, C. (2012). Farmers' willingness to participate in payment-for-environmental-services programmes. *Journal of Agricultural Economics, 63*(3), 604-626. doi:10.1111/j.1477-9552.2012.00358.x

McAfee, K. (2012). The contradictory logic of global ecosystem services markets. *Development and Change, 43*(1), 105-131. doi:10.1111/j.1467-7660.2011.01745.x

MEPyD-ONE. (2017) Boletin de estadisticas oficiales de pobreza monetaria, República Dominicana In, *Boletin semestral Vol. Año 2* (Octubre 2017 ed.). Santo Domingo, República Dominicana: Ministerio de Economia Planificación y Desarrollo-Oficiana Nacional de Estadistica.

MMARN. (2018). Avances REDD+ en República Dominicana. Retrieved from http://ambiente.gob.do/avances-redd-republica-dominicana/

Field Code Changed

Molina-Navarro, E., Martínez-Pérez, S., Sastre-Merlín, A., & Bienes-Allas, R. (2014). Catchment erosion and sediment delivery in a limno-reservoir basin using a simple methodology. *Water Resources Management, 28*(8), 2129-2143. doi:10.1007/s11269-014-0601-7

Montagnini, F., & Finney, C. (2011). Payments for environmental services in Latin America as a tool for restoration and rural development. *JSTOR*(40), 285-297. doi:DOI 10. 1007/s 13280-0 10-01 14-4

Naidoo, R., & Adamowicz, W. L. (2006). Modeling opportunity costs of conservation in transitional landscapes. *Conservation Biology, 20*(2), 490-500. doi:10.1111/j.1523-1739.2006.00304.x

ONE. (2007). Encuesta de ingresos y gastos de los hogares (ENIGH-2007). Available from Oficiana Nacional de Estadistica Retrieved 5/06/2017, from ONE http://redatam.one.gob.do/cgibin/RpWebEngine.exe/PortalAction?&MODE=MAIN&BASE=ENIGH2007&MAIN=WebServerMain.inl

ONE. (2010). IX censo nacional de poblacion y vivienda 2010. Available from Oficiana Nacional de Estadistica Retrieved 2/08/2017, from ONE http://redatam.one.gob.do/cgibin/RpWebEngine.exe/PortalAction?&MODE=MAIN&BASE=CPV2010&MAIN=WebServerMain.inl

Field Code Changed

Ovalles, P. (2011). Identificación de las causas de la deforestación y la degradación de los bosques en la Republica Dominicana. In *Programa REDDCCAD/GIZ en Centroamérica y República Dominicana*.

Peterson, J. M., Smith, C. M., Leatherman, J. C., Hendricks, N. P., & Fox, J. A. (2014). Transaction costs in payment for environmental service contracts. *Amer. J. Agr. Econ., 97*(1), 219–238. doi:10.1093/ajae/aau071

Polasky, S., Lewis, D., Plantinga, A., & Nelson, E. (2014). Implementing the optimal provision of ecosystem services. *Proceedings of the National Academy of Sciences - PNAS, 111*(17), 6248-6253. doi:10.1073/pnas.1404484111

PROCARYN. (2008). *Plan de manejo microcuencas El Caimito/Bajo Guanajuma* Proyecto Manejo y Conservacion Cuenca Alta Del Rio Yaque Del Norte (PROCARYN)

Comité de Microcuenca El Caimito/Bajo Guanajuma. Secretaria de Estado de Medio Ambiente y Recursos Naturales. Republica Dominicana.

Ravindranath, N. H., & Ostwald, M. (2007). *Carbon inventory methods: Handbook for greenhouse gas inventory, carbon mitigation and roundwood production projects* (Vol. 29). Dordrecht: Springer.

Santos, B. A. (1992). *Cost benefit analysis of soil erosion control: The case of Plan Sierra* (PhD Dissertation), University of California at Berkeley, California, USA.

Proyecto de ley de pago por servicios ambientales, 01442-2013-PLO-SE, Senado (2013) (Depositada el 2/4/2013. En Agenda para Tomar en Consideración el 3/4/2013. Tomada en Consideración el 3/4/2013. Enviada a Comisión el 4/4/2013. Informe de Comisión Firmado el 8/5/2013. En Agenda el 8/5/2013. Informe Leído con Modificaciones el 8/5/2013. En Agenda el 15/5/2013. Aprobada en Primera Con Modificaciones el 15/5/2013. En Agenda el 22/5/2013. Aprobada en Segunda Lectura el 22/5/2013. En Transcripción Legislativa el 23/5/2013. En Auditoría Legislativa el 27/5/2013. Devuelto a Transcripción Legislativa el 29/5/2013. En Auditoría Legislativa el 29/5/2013. Esperando Firmas Presidente y Secretarios el 5/6/2013. Remitido a Archivo y Correspondencia el 12/6/2013. Despachada el 13/6/2013. Perimida Cámara de Diputados al término de la SLO-2013.).

Snyder, C., & Nicholson, W. (2012). *Microeconomic theory: Microeconomic principles and extensions* (11 th ed.). India: Cengage Learning

Stern, N. (2007). *The economics of climate change: The Stern review*. Cambridge, UK; New York: Cambridge University Press.

Stoffberg, G. H., Rooyen, M. W., Linde, v. d. M. J., & Grounebeld, H. T. (2010). Carbon sequestration estimates of indigenous street trees in the City of Tshwane, South Africa. *Urban forestry & urban greening, 9*(1), 9-14. doi:10.1016/j.ufug.2009.09.004

Taylor, M. A. P., & Susilawati. (2012). Remoteness and accessibility in the vulnerability analysis of regional road networks. *Transportation Research Part A: Policy and Practice, 46*(5), 761. doi:10.1016/j.tra.2012.02.008

Tercera Comunicacion National, R. (2017). *Tercera Comunicación Nacional de la República Dominicana para la Convención Marco de las Naciones Unidas sobre Cambio Climático* República Dominicana Retrieved from http://unfccc.int/national_reports/non-annex_i_natcom/items/10124.php.

Field Code Changed

Van Hecken, G., & Bastiaensen, J. (2010). Payments for ecosystem services: Justified or not? a political view. *Environmental Science & Policy, 13*(8), 785-792. doi:https://doi.org/10.1016/j.envsci.2010.09.006

Wunder, S. (2013). When payments for environmental services will work for conservation. *Conservation Letters, 6*(4), 230-237. doi:10.1111/conl.12034