A Financial Case for Carbon Dioxide Sequestration and Commodification: Evaluating the *Reforest The Tropics* Program in Costa Rican Farm Forests

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Abstract: A financial case is made for a value proposition that carbon sequestration in Costa Rica provides a greater return to landowners than its opportunity costs. An introduction and background consider the topic of market-based mechanisms used for environmental policy and regulation. Policies and programs related to mitigation of climate change provide the context of this discussion. A literature review characterizes ecosystem services (PES) on a reforestation payment basis, identifying the high points of PES schemes' successes and failures as they relate to and help inform economic farm forestry in Costa Rica. Reforest The Tropics, Inc., a non-profit organization developing economic farm forestry in Costa Rica, is a base case to analyze carbon sequestration and commodification as an economically feasible enterprise. Carbon dioxide sequestration will comprise one leg of the financial analysis, capitalizing on biophysical quantities of sequestered carbon and different fixed and variable prices of carbon. Revenues, costs, and net present values derived using a range of discount rates represent another side of the financial analysis. In the end, a set of meaningful scenarios for carbon dioxide commodification is translated into a suite of core products that can be marketed to potential project-seeking farmers and landowners in Costa Rica.

INTRODUCTION

In the past five years, the global conversation around climate change has ripened. That is, experts from the scientific community to the political arena have moved beyond posing positive questions, *does climate change exist?* to soliciting normative questions, or *what should we do about it?* The shift in paradigm to normative questions, or what *should* or what *ought* we do about climate change, is a prerequisite to taking action on climate change. The latter is a prescription for both climate mitigation and adaptation strategies. Furthermore, climate mitigation strategies are pre-emptive in nature, aiming to reduce global greenhouse gas emissions. Adaptation strategies lessen human vulnerability to climate change, and hone risk management to curtail the likelihood of damages and consequences caused by climate change. One such mitigation solution is carbon sequestration, a cornerstone in this study. Mitigation and adaptation act as a double-pronged approach for climate change policies on national and global scales. Even if the world stopped emitting all sources of greenhouse gases over the next decade, damages from climate change would still manifest over the decade and into the future. Therefore, a mixed portfolio of strategies that employ both mitigation and adaptation efforts is becoming commonplace for climate policymakers across the globe.

The Kyoto Protocol

The watershed moment thus far in global climate policy history is the Kyoto Protocol, the first international agreement and treaty developed in tandem with the United Nations Framework Convention on Climate Change (UNFCCC) in Kyoto, Japan in 2005 (UNFCCC, 2014). If nothing else, the Kyoto Protocol is a symbol for unprecedented environmental diplomacy and convergence on the global stage. The UNFCCC's framework for international climate change cooperation gave rise to the Kyoto Protocol's adoption in 1997. The hallmark of the Kyoto Protocol is its legally binding greenhouse gas emission reduction targets (UNFCCC, 2014). Although the inception of the Kyoto Protocol occurred on December 11, 1997, it did not go into effect until February 16, 2005. The UNFCCC laid the groundwork for the Kyoto Protocol (UN, 2014). Countries signed the Convention in May 1992, however, governments thought the Convention would fall short of their climate change goals. In 1997, the Kyoto Protocol was in its infancy as an extension of the Convention, specifically targeting developed countries that underwent massive industrialization (UN, 2014).

For the Protocol to launch, 55 countries in the Convention, called Parties, had to ratify the treaty. The Convention held these countries accountable for their legally binding greenhouse gas emission reduction targets during a specified timetable (UN, 2014). The Protocol categorized developed nations as the largest emitters of greenhouse gases because of their post-industrial statuses. The Protocol saw these nations as the strongest heavy-lifters for climate change, especially since the treaty deployed mechanisms to help industrialized nations achieve their emission reduction targets (UNFCCC, 2014). Inevitably, the Kyoto Protocol saddled developed countries with the most challenging climate change mitigation strategies, which each country had to implement through national measures and programs (UN, 2014). During what is coined the 'First Commitment Period,' the Protocol instituted a binding emission reduction target of five percent using 37 countries' 1990 emission levels as a baseline (UN, 2014). A second commitment period seeks to reduce levels 18 percent below 1990 levels in an 8-year time period between 2013 and 2020 (UNFCCC, 2014).

Leaders point to the Protocol as a demonstrative and successful international endeavor because it acted on global awareness of climate change. Beyond awareness, it channeled international fear and risk of climate change threats to structure a semi-baked model for international action on climate change (Victor, 2001). In many regards, the Protocol was plagued with loopholes and vague policy delegations. For many developed countries, the decision to ratify the Kyoto Protocol was a race against the clock. For example, the United States' emissions were steadily rising whilst it decided to ratify the Protocol (Victor, 2014). Countries exhibited a widening gap between their emission targets and their actual emissions, a red flag that governments had overly grandiose ideas about their targets. However, a widening gap also signaled that there were underlying regulatory flaws in setting reduction targets (Victor, 2001). Governments were not adequately equipped with the anticipatory know-how to set emission reduction levels (Victor, 2001).

The Protocol grappled with considerations such as how to incorporate *developing* countries into the calculus. Developing nations are the largest emitters of greenhouse gases today, and in two decades, they will outpace developed nations in total greenhouse gas emissions (Victor, 2001). Unfortunately, the Protocol dealt with a classic case of the North versus South debate, a politically-charged argument where the industrialized North argues the developing

South should curb its greenhouse gas emissions. The South, conversely, maintains that is has the 'right to emit' because the industrialized North had the same opportunity. Furthermore, another crucial consideration is deforestation. Today, deforestation accounts for 20 percent of all anthropogenic global carbon dioxide emissions (Gullison et al., 2007). Because deforestation is such a large offender of climate change, it introduces the risk of reversing the Kyoto Protocol's original goals. For example, deforestation in Brazil and Indonesia *alone* accounted for four-fifths of the annual reduction of carbon dioxide emissions mandated by Kyoto from 2008 to 2012 (Stern, 2006).

Above all, the Protocol's framework for addressing the *costs* involved in meeting countries' emission reduction targets was tangential instead of core (Victor, 2001). Conditional upon meeting their Kyoto reduction targets, governments would have to revamp their national economies in drastic ways. Thus, one of the most prompting questions stemming from Kyoto was how Parties could meet their emission targets in a cost-effective manner (UNFCCC, 2014). Fortunately, the Protocol outlined three means by which it could help countries meet their emissions reduction targets: 1) international emissions trading, 2) the Clean Development Mechanism (CDM) and 3) Joint Implementation (JI) (UNFCCC, 2014). In essence, these three mechanisms were the basic scaffolding for establishing a world carbon market (UNFCCC, 2014). These mechanisms also facilitate green investment between countries and help countries achieve their reduction targets in economically feasible ways (UNFCCC, 2014). More importantly, critics of the Protocol identify these cost-saving mechanisms as the linchpins for viable and timely attainment of countries' reduction targets and for slowing global climate change (Victor, 2001).

BACKGROUND

Introduction to Market Mechanisms

The Kyoto Protocol was an invaluable policy for spurring further research on *market-based instruments* (MBIs) to address climate change (Victor, 2001). A MBI, as it applies to both climate change mitigation and adaptation strategies, is an environmental law and policy instrument that relies on markets, prices, or other economic variables to deliver incentives to emitters that agree to reduce emissions. MBIs are the umbrella term used to encompass a slew of economic tools and sanctions such as taxes, charges, fees, fines, penalties, liability and compensation, subsidies, and tradable permits (UNEP, 2009). Although the definition of a MBI is subject to change based on the environmental context, all MBIs have underlying elements (UNEP, 2009). By convention, when an economic tool or sanction changes the price or cost of a good or service in the market, it is a market-based instrument. Alternatively, an economic tool that changes the quantity of a good can also be classified as a market-based economic instrument. MBIs are preferred over explicit directions for pollution control efforts because they are put into the polluter's own terms, and with synergistic effects, they can achieve wide-reaching policy goals (Stavins, 2003).

The notion of marginal cost is applicable to every market-based instrument. In short, MBIs spread the *additional* costs associated with greenhouse gas reduction across firms, which firms incur as a *marginal* cost (Stavins, 2003). MBIs should, theoretically, render pollution reduction at its lowest overall cost to society. By means of allocating the largest incentives for the greatest pollution reduction, MBIs are conducive to firms that can reduce pollution most cheaply (Stavins, 2003).

Categories of Market-Based Instruments

There are several categories of market-based instruments, however, for the purpose of this study, the focus will be on the Clean Development Mechanism (CDM) under the Kyoto Protocol and the UN-borne REDD Program (Reducing Emissions from Deforestation and Forest Degradation). The CDM, found in Article 12 of the Protocol, enables a Party with an emissions-reduction or emissions-limitation commitment, to turn to a developing country to achieve emission reductions. That is, a Party can initiate an emissions-reduction project in a developing country as a legitimate avenue to meet target goals (UNFCCC, 2014). Examples of viable CDM projects in developing countries include electrification using solar panels and reforestation efforts (UNFCC, 2014). The United Nations, in particular, has a high number of CDM forestry projects (UNFCCC, 2014). In the case of reforestation, this study examines carbon as a payment for ecosystem services, certified emission reduction credits (CERs) and ecosystem services, and the intersection between them. As a product of time and an ecosystem service such as carbon sequestration, CDM emission-reduction projects in developing countries generate streams of CERs. Each credit is equal to one ton of carbon dioxide and can apply toward Kyoto reduction targets. CERs compose the largest group of compliance credits on the carbon market and can only be generated through projects in developing countries (Carbon Planet, 2009). The thorny question regarding CERs is the price at which CERs are sold (Jayachandran, 2013).

Many Kyoto leaders herald the CDM as the world's first environmental credit scheme, particularly pertaining to offsets (UNFCCC, 2014). The CDM is a purveyor of the added flexibility developed nations require to realistically meet their reduction targets (Victor, 2001). While robust enough to foster sustainable development and significant emissions reductions, the CDM is also the low-hanging fruit. Developing countries in which CDM projects are implemented are exempt from the Protocol (Chadwick, 2006). Therefore, host countries of the CDM have no legally binding commitments to emissions reductions under the Protocol. As a result, there is little incentive for the project-developing country to reduce its emissions (Chadwick, 2006). In response to this concern, there are certain conditions that a CDM project must meet with respect to baseline emissions (Chadwick, 2006). The baseline for emissions, or the 'business as usual' baseline, is especially important because CERs theoretically represent the difference between baseline emissions and overall observed emissions (Chadwick, 2006). In most cases, this difference between baseline emissions and observed emissions cannot represent greenhouse gases *removed* from the atmosphere. Instead, this difference projects the *transfer allocation* of emissions from the host country to the developed country (Chadwick, 2006).

The CDM ignores the poverty contexts in developing countries, a fundamental socioeconomic factor that cannot be dismissed. Opposition to the CDM claims that the livelihoods of self-employed and land-owning people in developing countries are disregarded during a game of The Race to the Bottom (Jayachandran, 2013).

Market-Based Instruments versus Regulation

It is important to explore the differences between market-based instruments, regulation, and their relationship. Once regulation is a factor through government intervention, firms must weigh the option of purchasing carbon offsets against reducing emissions. The option a firm will pursue should be the lowest-cost option because the firm is *forced* to comply with government standards or policies. Furthermore, market-based instruments are a very promising tool for environmental policy makers (Gayer & Horowitz, 2006). Moreover, economists have historically pushed environmental policy makers to harness the power of MBIs for well-argued reasons. Market-based mechanisms help achieve environmental goals in the most cost-effective manner through the power of incentive-based coercion (Gayer & Horowitz, 2006). Nevertheless, the flow of incoming financial benefits should match the marginal cost of outputting an additional ton of carbon dioxide into the atmosphere (Stern, 2006). Secondly, MBIs are effective at internalizing negative environmental externalities.

Thus, there is a close overlay between market-based instruments used as tools for environmental policy. For example, a firm that purchases carbon offsets (abatement) can consider it an emissions *reduction* plan. When a policy requires firms to regulate their carbon dioxide, they can buy offsets as a means of policy compliance. A U.S. firm might turn to a local cap-and-trade program, such as California's notable greenhouse gas program, or the Regional Greenhouse Gas Initiative (RGGI) cap and trade program in New England, as a means of compliance by purchasing offsets. Theoretically, prices should be higher on the compliance market because demand is high and relatively inelastic. A voluntary carbon market, on the other hand, should exhibit lower prices and more elastic demand since it is the vehicle for do-gooder business and individuals to purchases offset credits (Gayer & Horowitz, 2006).

Reducing Emissions from Deforestation and forest Degradation (REDD and REDD+)

The UN REDD Program was launched in 2008 as an international climate change mitigation strategy (Ali et al., 2010). REDD's trademark is *avoided* deforestation and forest degradation in developing countries. The key is *avoided* because REDD allows 'avoided deforestation' value propositions to tap carbon markets. Furthermore, REDD operates on a platform similar to, yet also fundamentally different from, the CDM (Ali et al., 2010). High-emitting developed countries pay developing countries to prevent deforestation or degradation of land. Eager to take action, the UN strategically built REDD around the third largest global offender of climate change—deforestation and forest degradation activities (Ali et al., 2010). The UN's approach to apply pressure on a significant driver of climate change was, in part, to reduce pollution sufficiently and in time to ward off climate change's foreboding threats (Ali et al., 2010).

In a REDD contract, countries have a clear economic incentive to avoid future deforestation and forest degradation through the mobilization of funds from developed countries. REDD+ is slightly differentiated because it gives countries the additional option of practicing sustainable forest management (Ali et al., 2010). REDD+ is the merger between carbon benefits in the form of increased carbon stocks in forests and ancillary benefits, most of which are environmental like water and soil conservation. Unlike the CDM under Kyoto, REDD and REDD+ allow for more forestry projects. Developed countries that fund projects under CDM do not have the option to fund avoided deforestation' projects. There is a small category under CDM for afforestation and reforestation projects, however, they are narrowly defined and small in scope (Ecosystem Marketplace, 2014). Developed countries can purchase offset credits from developing countries for avoided deforestation. Above all, REDD has succeeded because it places a financial value on stored carbon in forests (UN-REDD Programme, 2014). For this financial template to work, the commercial benefits of deforestation and natural resource extraction cannot exceed the commercial benefits associated with stored carbon in forests (Carbon Planet, 2009).

The Kyoto Protocol did not incorporate the REDD mechanism with its three emission reduction mechanisms because of scant information on deforestation emissions and monitoring at the time. As a result, REDD is not a part of the regulatory market whose carbon prices grew 9 percent in lockstep with the Kyoto Protocol's rollout of emission reduction mandates (Gogo, 2014). Instead, REDD offset credits are sold on the smaller voluntary market where buyers purchase relatively cheap REDD project credits for reasons *other than* compliance with policies or laws (Ecosystem Marketplace, 2014).

REDD+ and Fair Trade

The REDD+ scheme draws several parallels to a Fair Trade system's basic criteria. The sustainable management component to REDD+ is meant to insinuate other economic, social, and environmental benefits that complement a practice. According to the UN-REDD Programme, REDD+ strategies can improve the livelihoods of forest managers and custodians (2014). Proponents of REDD+ highlight the opportunity for sustainable development in poverty-stricken, countries without needing to rely on time-consuming technology implementations (EDF, 2014). They also advocate for REDD+ using but-for causation: but for REDD+, deforestation and climate change would gravely devastate indigenous communities who rely on tropical forests for their livelihoods. REDD+ projects lift indigenous communities out of poverty by providing them with a fast and new means of increased income. In addition, they protect biodiversity and the integrity of ecosystem services, and reinvigorate marginalized communities who are the figureheads of poverty contexts and tropical forests in developing nations (EDF, 2014).

Opposition to REDD and REDD+

Despite their loose ties to the Protocol, REDD and REDD+ mechanisms have received modest backlash. Critics and environmentalists highlight pitfalls of REDD schemes. REDD+ promotes a sense of fair play, much like a Fair Trade scheme, through its delivery of ancillary benefits to the environment and local communities. However, much like the CDM, REDD schemes are often transient of and have no appreciation for poverty contexts in which they are designed to operate (IPS, 2013).

Furthermore, there is a cadre of critics that oppose REDD schemes because they produce a stream of offsets. For the developed country, purchasing REDD offset credits from a country thousands of miles away *is* a reduction strategy (IPS, 2013). So long as the country purchases credits from the host country, there is a perverse incentive for the purchasing country to not reduce its domestic emissions. However, purchasing countries view *avoided deforestation* as an authentic reduction strategy (IPS, 2013). By this logic, countries are not addressing the roots of climate change and are instead diverting their attention from important and available technologies such as energy efficiency and renewable energy (IPS, 2013). This represents capitalist behavior because countries can legally purchase offsets to mask their continuous pollution. To counter this approach, critics argue that countries should reduce emissions through innovative measures, without using offsets as a buy-out (IPS, 2013). Therefore, some argue that offsets should be temporary placeholders until countries can implement effective domestic reduction strategies.

Lastly, critics have doubted the certainty and efficiency of the carbon market. If the carbon market is not capturing the value of standing trees, a scheme like REDD could be a rigged and lopsided reward system. For both developed and developing countries to meet their twin goals of curbing deforestation through REDD schemes, the financial system must be administratively well-structured, transparent, and highly incentivized based on performance (Noordwijk, 2008). Similarly, REDD credits must be verifiable, measurable, and reportable to ensure an adequate level of project governance and oversight.

LITERATURE REVIEW

Introduction to Payments for Ecosystem Services (PES) Programs

Payments for Ecosystem Services (PES) represent an overarching classification of policies that are designed to do as the name suggests. That is, PES schemes compensate individuals or communities for their pro-environment behaviors and actions that, in turn, ensure ecosystem service provisioning into the future (Jack et al., 2008). The currency of PES policies centers on ecosystem services like water purification, flood mitigation, and carbon sequestration (Jack et al., 2008). Payments are awarded conditionally to individuals and communities partaking in such behaviors and actions (Jayachandran, 2013). Furthermore, because PES schemes are highly incentivized, there is a greater probability that individuals and communities will undergo pro-environment behavior change (Jack et al., 2008).

Payments for ecosystem service programs fall under the banner of incentive-based mechanisms, one subset of market-based instruments used in environmental policy (Jack et al., 2008). PES schemes change the price of environmental protection relative to environmental degradation through rendering environmental protection more profitable than environmental degradation on the same land. For this reason, payments for ecosystem services are market-based instruments (Jack et al., 2008). As in the case of all environmental policy theories, payments for ecosystem services can internalize negative externalities (Pattanayak et al., 2010). Economists argue the benefits of ecosystem services are a positive externality of nature itself, however, society has not successfully delegated an artificial means by which to internalize these positive externalities to the same accord (Pattanayak et al., 2010). PES policies are gleaned for bridging the gap between both extremes in a cost-effective way (Jayachandran, 2013). The contract between the beneficiary (buyer) and provider (seller) of ecosystem services delivers payments in the form of subsidies to the providers of ecosystem services. Since all subsidies result in a positive externality, there is a sense of an over-inflated supply of ecosystem services (Pattanayak, 2013). This change in quantity of ecosystem services also constitutes PES policies as a MBI. Unfortunately, successful PES schemes can be hard to come by, especially when the economic, political, and social circumstances of developing countries exhibit powerful forces over a PES economic theory.

Categories of Payments for Ecosystem Services Schemes

While there is a registry of PES programs across the world, this study examines PES schemes categorically for carbon sequestration. Subsequently, past literature reviews are cited based on the stories they tell about payments for ecosystem services relative to economic farm forestry in Costa Rica. For all categories of PES schemes, it is important to reflect equally on land use (i.e. forests and agriculture) and deliverable benefits (i.e. carbon dioxide sequestration, economics to farmers, and biodiversity).

PES Schemes for Carbon Sequestration

Countries such as Mexico, Costa Rica, and China have adopted an economic lens through which to view forest conservation provisioning in the future (Corbera et al., 2008). Recently, these countries have established national PES schemes whereby governments pay farmers and rural communities for future environmental services provisioning (Munoz et al., 2006). In the case of Mexico, carbon sequestration is a perceived form of market-based climate regulation. Government actors also operate in the same arena as NGOs and other private incubators that pay farmers for reforestation efforts (Landell-Mills and Porras, 2002). Governments and companies in developed countries are the financial backers of forest conservation and reforestation projects throughout the developing world. Furthermore, the voluntary carbon market has been the primary means through which these entities have offset their emissions, while Kyoto’s CDM has waned in global project registration (Bayton et al, 2007).

In Mexico, carbon payments for reforestation efforts have placed a higher price on ecosystem service provisioning than traditional alternative land-uses activities (Corbera et al., 2008). However, other important climate strategies such as education and efficient technology should be on the political agenda, nonetheless (Engel et al., 2008). In particular, Mexico has been relatively unsuccessful in marketing its sustainable forest management conservation initiatives on a national scale, considering it is one of the most deforested places in the world (Corbera et al, 2008). Researchers attribute Mexico’s widespread deforestation to conversions of forests to pastured lands suitable for agricultural purposes, especially when conservationist will is minimal or lacking. In response, the Mexican government adopted the PES financial institution to stimulate pro-environment behaviors such as forest conservation and reforestation in rural communities (Klooster, 1999). In 2004, the Mexican government implemented a programme for Payments for Carbon after it had launched one of the first carbon forestry programs in the world (Corbera, 2005). Over the years, Payments for Carbon evolved to ensure long-term beneficiary commitment to projects and to meet international standards and management costs. In that context, organizations posited that new markets would eventually pair up PES service buyers and providers (Corbera et al., 2008). Additionally, the programme drafted specific rules for project design as a guiding mechanism for successful project implementation and a hedge against compromised future project performance (Corbera et al., 2008). Eventually, carbon rules aligned with those for small-scale afforestation and reforestation projects under the CDM. As a result, projects were implemented on a large-scale basis (typically 500-3000 hectare plantings) and produced voluntary and CDM offsets (Bayon et al., 2007).

Above all, rural communities have elicited positive responses to payments for carbon services in the past few years. In fact, carbon payments contribute significantly to average household and community income. PES carbon schemes that incentivize reforestation should create an equal and annual level of value proposition to affect behavior change (White and Martin, 2002). Furthermore, the carbon program is a gateway to future forest provisioning, which in turn, will generate future benefits for those that are faithful caretakers (Corbera et al., 2008). Moreover, the organizational structure for project funding is divided between an intermediary (71%) who provides technical assistance and a third-party project certifier (29%) (Corbera et al. 2008). Interviewed individuals advocated for higher carbon payments and proposed financial support after the project’s five-year launch period (Corbera et al., 2008). Under this condition, farmers are more likely to opt out of their current land use practice for a carbon project. By observation, long-term partnerships between service providers and intermediaries bolster participation in carbon projects (White and Martin, 2002).

One of the largest unknowns facing carbon projects is the fate of the carbon market. Moreover, it is hard to gauge investor interest in project development due to the market’s high volatility and lack of regulations in developed countries (Boyd et al., 2007). Quantifying ancillary benefits of carbon projects (i.e. avoided soil erosion and ground water protection) to increase the overall cost-effectiveness and justification of a carbon project is also difficult (Boyd et al., 2007). To garner international investor support in carbon projects, marketing efforts that link carbon forestry projects to CDM and voluntary markets are necessary (Millennium Ecosystem Assessment, 2005).

In cases of landowner disenchantment, incompetent project intermediaries hamper the financial success of the project (Corbera et al., 2008). Project proposals are notorious for leaving informational and logistical gaps in project implementation, and effective structuring of proposals are keystone for long-term landowner acceptance and retention (Pagiola, 2008). Likewise, service providers are often unable to conceptualize carbon project design, implementation and interactions, initially creating information asymmetry in the power relationships between intermediaries and sellers (Wunder et al., 2008). In one case in southern Mexico, the financial architecture of a project contributed to inequalities in payment access, resulting in disputes among farmers and communities (Corbera et al., 2007). Government PES programs, on average, are less promising in ensuring conditional payments because financing is front-loaded (Wunder et al., 2008). Government funding can also be quickly siphoned, which affects funding flows for receiving service providers. Nonetheless, once government payments stop flowing to the individual, land use management either plateaus or tapers due to lack of financial incentives. International policy developments, however, will ultimately dictate the payment system type of carbon PES projects (Corbera et al., 2008).

Overall, carbon PES schemes in countries have tapped a new economic market that values the *service* of carbon sequestration as an *ecosystem service* (Cobera et al., 2008). Put differently, reforestation is a *valued* service for climate regulation. Whereas a market for this valuation did not previously exist before the 1990s, PES financial structures are newfound pillars. Local communities have benefited from equitable payments and adopted organizational skills surrounding forest management (Corbera et al., 2008). A valuable lesson learned is to ensure a certain level of project capacity and to foster greater understanding among all cooperating actors through both government and private intermediaries (Corbera et al., 2008). Not only must the service provider feel she is capturing value, she must understand the deliverables of a PES scheme on an elementary level (Cobera et al., 2008). This, in part, can be communicated through well-structured project proposals and contracts that establish long-term financial mechanisms for payments (Biermann, 2007).

In the future, carbon payments should place higher emphasis on *avoided deforestation*, as in the case of REDD, to introduce new types of contracts and to increase service provider participation (Corbera et al., 2008). PES participation is voluntary based on the consideration of other opportunity costs, and PES should continue to provide an attractive incentive to forgo alternative degrading land uses. Similarly, PES carbon contracts are perhaps the best insurance against project failure and information asymmetry between contract provider and service provider (Peskett et al., 2007). A better understanding of project capacity discrepancies between government-led and user-led programs warrants specific research. According to Wunder et al., private initiatives, compared to government programs, provide more targeted and negotiated payments between the intermediary and service provider (2008). It is crucial to erode impending barriers to project participation such as conflicting actor interests and incentives, non-land holding service providers, and conflicting environmental policies across scales and countries.

Further research should consider human behavior changes as a result of improved PES incentives, which could theoretically contribute to the integrity of carbon programs and ecosystem services (Biermann, 2007). Furthermore, the coexistence of government and intermediary programs is a powerful and overlooked requirement to diminish contradictory policies and actions across carbon programs. Government and intermediary dissonance deters participation and amounts to potential service provider confusion of PES design and incentives (Biermann, 2007). In that sense, geographical and political scales and contexts are important considerations for the service provider (Corbera et al., 2008). Additionally, multiple actors can complicate cooperation, and therefore, undercut design system and goals (Corbera et al., 2008). Therefore, a well-structured system transfers clear incentives from one actor to the next, which has simultaneously bolstered international support for projects and maximized actor cooperation. Project intermediaries should be held accountable to develop a clear set of rules that define actors' rights and responsibilities and project oversight (Biermann, 2007). They should also be responsible for developing new and adaptable project frameworks that deliver payments over longer periods of time. Corbera et al. maintain that payments are not always an absolute; service providers feel more engaged in their projects when payments are attractive *and* the benefits of social and environmental good are equally authenticated (2008).

REFOREST THE TROPICS' MODEL FOR SUSTAINABLE ECONOMIC FARM FORESTRY IN COSTA RICA

Reforest The Tropics, Inc. (RTT) is a privately funded 501(c)(3) non-profit organization and UNFCCC-AIJ (Activities Implemented Jointly) Climate Change Program and Sponsored Carbon-Offset Program based in Mystic, Connecticut. Since it received its license to operate a UNFCCC project in 1995, RTT has been making a tangible and active contribution to global climate change through environmental education in schools and applied research on carbon-offset economic farm forests in the Turrialba region of Costa Rica. Approved by both the U.S. and Costa Rican governments, its initial project was to manage a U.S. Initiative on Joint Implementation (USIJI). In addition, the state of Connecticut recognizes RTT as a way for its citizens to voluntarily offset their carbon emissions. In the present UN Program, RTT is the project manager of 148 hectares (ha) of tropical forest research plots for 80 U.S. donor accounts. The organization's own justification for innovative applied research relies on three principles:

1. Climate change and carbon sequestration are important issues, and therefore, merit research funding.
2. Costs of RTT are small.
3. Probability of success in long term carbon capture and storage is high.

RTT uses this justification for applied research because there are other worthy causes for forest sponsor donations.

RTT establishes *linkage* between U.S. carbon dioxide emitters (i.e. schools, small businesses, and corporations) and farmers and their forests in Costa Rica, underscoring the notion that effects of climate change are global. Linkage is connecting U.S. carbon emitters and farmers in Costa Rica via photos, forest management reports, and wood signs in the forests. In RTT's model, emitters of carbon dioxide fund demonstration projects in Costa Rica to offset their emissions in the U.S.

Tropical forests are a major sink of carbon dioxide. As such, carbon sequestration in tropical forests is the important niche within the broader range of climate change strategies that RTT chooses to occupy. RTT creates a case for carbon sequestration in tropical forest trees. Similarly, applied research makes a solid case for demonstration tropical farm forests in Costa

Rica. RTT estimates the cost of carbon dioxide sequestration in tropical forests to be within a targeted range of $8-$15 per metric ton (MT). A more in-depth explanation of how RTT arrived at these numbers will be discussed in the Financial Analysis section. In addition, RTT aims to deliver more benefits such as increased thinning incomes to its contracted farmers and ecosystem service provisioning.

Provided that U.S. carbon dioxide emitters are heedful of climate change mitigation options, they prioritize based on incurred costs. RTT also makes the financial case for forest offsets over other climate mitigation efforts. Nevertheless, emitters can select the mitigation efforts they find worthy of financing. Among competing options are purchasing Renewable Energy Credits (RECs) from wind power, installing solar panels, and purchasing offsets on the voluntary carbon market. A sponsored forest through RTT can generate a line of carbon credits for the donor over a 25-year contract lifetime. However, the forest sponsor cannot sell these offsets on the voluntary carbon market. Currently, the donor is not deriving direct commercial earnings from its offsets. Rather, the string of offsets has good-will and theoretical offset value because RTT is in a demonstration and research phase. With further expansion, RTT could reach an investment stage, especially if the government requires small and medium-sized U.S. emitters to balance their emissions. In addition, regulation is a factor that could theoretically place more value on *stored* carbon. For instance, the U.S. government might regulate emitters by forcing them to offset their emissions at a price of $10/MT. When regulation has a stranglehold on emitters, stored carbon that was a previously frozen asset becomes an added income overnight. That is, if an emitter already has captured carbon dioxide, the emitter would not have to pay $10/MT. In an alternative situation, it might cost emitters $30/MT in the future to emit carbon. RTT posits that forest carbon capture will be cheaper when firms are required to offset in the future. Therefore, carbon is gaining a greater economic value due to increasing demand to offset.

Figure 1. **RTT Model for Carbon Sequestration in Costa Rica**. Note: Carbon offsets are the ambiguous part of the model because their value is variable. Diagram courtesy of Dr. Herster Barres, Director, Reforest The Tropics Inc.

The key rule governing carbon sequestration in economic farm forests is *additionality*, as set forth by the UN for the Kyoto Protocol's three mechanisms. Moreover, RTT makes the case for *reforestation*, rather than forest conservation, because already existing tropical forests do not count as *new* carbon sinks. Forests must be planted on land *in addition to* pre-existing forests for existing forests to serve as the benchmark from which to work. In the same vein, the UN addresses the problem of *leakage*. In this context, leakage refers to the unanticipated increase in carbon emissions outside of a project's accounting boundary that results from an aggregation of the project's activities (Schwarze et al., 2002). Leakage is a concept that pertains to reforestation and afforestation projects in developing countries. In RTT's case, gasoline is required for cars and trucks to access forests. With respect to leakage, emissions created are also emissions deducted from total carbon dioxide capture and storage in forests.

RTT has four goals for applied research on demonstration forests in Costa Rica:

1. *Achieve 500 MT carbon sequestration total/hectare/25 years (contract lifetime)*
2. *Generate $500 (U.S. dollars)/hectare/year for the farmer*
3. *Store carbon dioxide for the long-term (100+ years)*
4. *40 MT/hectare/year of stored carbon*

Furthermore, assuming a 20 MT/year yield rate for carbon storage * 25 years of an RTT contract with a farmer **= goal of 500 MT/hectare carbon storage over the lifetime of a RTT contract.**

To achieve its goals, RTT is a *designer* of forests. RTT hones mixed-species forest management and design to help ensure biological survival and long-term, 100+ year carbon storage. On average, RTT plants 5-6 tree species, some of which include fast-growing tree species that are readily available for the farmer's first thinning income and some of which are slow-growing species to allow for subsequent thinnings. In particular, RTT has begun to plant cedar trees in its forests because cedar commands a high price on the timber market. In direct contrast to conventional wood harvesting, RTT does not thin its best growing trees. Rather, it thins the second best tree to enhance the growth rate of the best tree through reduced competition. Thinnings in its new model are expected starting at year 8 and every four years after (year 12, 16, 20, and 24.) Whereas loggers have little incentive to place a value on stored carbon, RTT points to clear incentives. To ensure a lasting value, RTT's partial harvesting system is a 20 percent reduction in forest biomass, leaving the best trees in the ground. The standing trees take on an economic value for *stored* carbon, even if they are not thinned for commercial use. In the contract with a farmer, he agrees that RTT will manage the forest for the contract duration. That said, loggers who are contracted to cut trees do not always follow the forest manager's instructions, prompting considerations for how to avoid this problem. In an attempt to ensure future forest management provisioning, RTT must maintain strong relationships with its farmers. As a consolation, the farmer also has 12 years before he exhausts carbon payments, which will be discussed in the Financial Analysis.

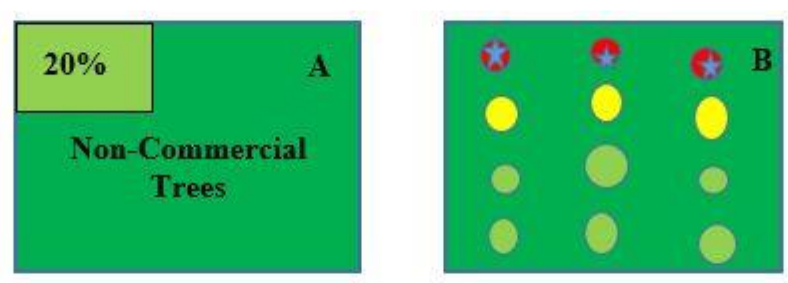


Figure 2. RTT Farmer Income from Thinnings. Diagram A represents a logger's harvest. The light green box in the top left-hand corner represents a 20 percent harvest of the best trees (highest quality and fastest growing). The rest of the trees left behind are lower qualities that are not conducive for commercial sale or for long-term carbon storage. Diagram B represents RTT's 20 percent competitive thinning program. The biggest competitor (red with stars) to the best trees (yellow) are thinned. An aggregate of leaving the best trees behind lends to long-term carbon

storage. Trees are different shapes, sizes, and spaces apart to represent RTT diverse forest design. Diagram courtesy of Dr. Herster Barres, Director, Reforest The Tropics, Inc.

RTT's Environmental Payments for Incremental Carbon Capture (EPICC) Model

Paramount to RTT's nearly 20 years of applied research is a new and innovative model dubbed *Environmental Payments for Incremental Carbon Capture (EPICC)* that is currently being tested. The EPICC model closely mirrors a 'pay-as-you-go' plan for sequestered carbon. It is designed, in particular, with the farmer and his overall financial well-being in mind. Part of this model assumes that RTT is sharing the future value of stored carbon with a farmer. That is, a farmer captures the value of wood in a standing tree after thinnings. The thrust of this model, however, is rendering reforestation financially compelling for farmers and capturing and storing carbon on behalf of the U.S. emitter. This model initially offers free technical assistance to the farmer with a $2,000 grant. At this point, the $2,000 grant presells carbon credits for the 25 year contract. The EPICC model introduces annual carbon payments for the farmer at the end of year 4 of the contract, hence, payments for incremental carbon capture (i.e. no payment until year 4). RTT is paying a landowner for *annual* and *incremental* carbon capture in forests. The cash flow for carbon payments continues until a payment ceiling of $2000, which is expected to occur at the end of year 12. Above all, the EPICC model positively manipulates the farmer's cash flow in three important ways: a) jumpstarts farmer cash flow earlier in the contract, b) diversifies her income depending on competing options which are addressed in this study, c) and closes the gap between long periods (3-4 years) without income.

Costa Rican National Payments for Ecosystem Services Program

Costa Rica has declared its goal to become the world's first carbon neutral country by 2021. Notably, half of the country's land is covered by forests, posing significant geographic competitive advantage. Officials are focused on converting pastured land used for agricultural crops and cattle ranching into reforested areas by planting 7 million trees on roughly 50,000 plantations (Boddiger, 2012). According to the World Bank, forestry efforts alone will be the largest barometer of success: approximately 72 percent of the 2021 goal will be met through forestry. Not surprisingly, there is a growing demand in Costa Rica for land on which to plant forests (World Bank, 2013).

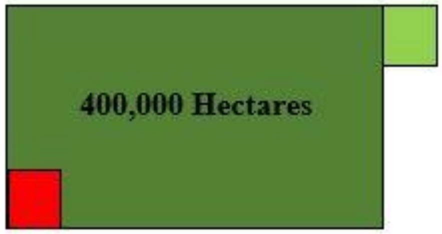


Figure 3. Costa Rica's Government Model. The government maintains 400,000 hectares of tropical forests at all time, where dark green represents 400,000 hectares of tropical forests, red represents a logged section of mature tropical forests, and light green represents a new planting of immature forests to compensate for the red area. The logged section of immature forests results in less total stored carbon, and ultimately, represents a net loss. Diagram courtesy of Dr. Herster Barres, Director, Reforest The Tropics, Inc.

FONAFIFO, a Spanish acronym, is the governing body that collects PES funds and is responsible for the overall management five PES forest activity categories in Costa Rica—protection, reforestation, regeneration, forest management and agroforestry. The current government PES model for *reforestation* offers a landowner $980/ha/contract for agreeing to plant any tree species (regular reforestation) and $1470/ha/contract for agreeing to plant native species (Porras et al., 2013). Payments are offered for a contract period of 15 years, but are only issued during the first five years of the contract. A landowner in Costa Rica receives an average $1,000/ha/contract to reforest pastured land that was previously used for crops or for cattle ranching (Porras et al., 2013).

In Costa Rica, there is cultural pressure to plant native trees even though there is a mantra of critics that advocate for exotic species. Originally, farmers were planting native species as part of the 2021 plan for carbon neutrality. However, native trees are slower growing than non-native species, and consequently, farmers have turned to primarily monoculture plantings. Lastly, these monocultures are cut down within 5-8 years after planting because there is little incentive to keep them in the ground. They are susceptible to mass decimation from disease due lack of genetic diversity. On the other hand, the Costa Rican government is trying to establish the right medium through which to sell its carbon offsets. In the past few years, Costa Rica has captured more than 90 million tons of carbon dioxide. However, due to the lack of an international compliance market on which to sell its carbon offsets, the country is focusing its efforts on a national market for buying and selling carbon credits (Salazar, 2014). These saleable offsets are traded among businesses, organizations, and individuals seeking to offset 'unavoidable' emissions (Salazar, 2014). Ultimately, Costa Rica plans to establish an international carbon market with credits flowing from forestry activities (Salazar, 2014).

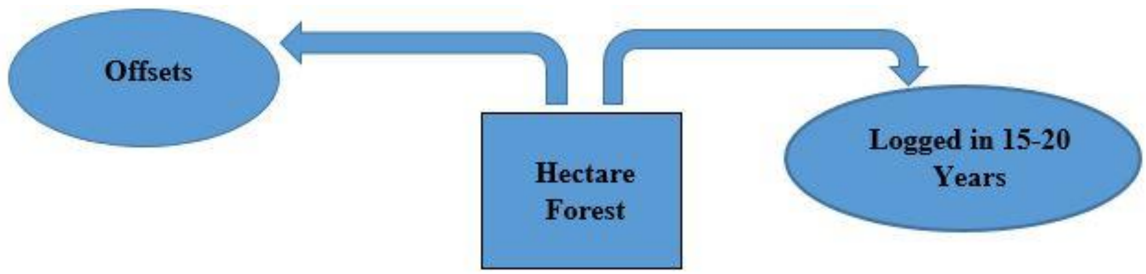


Figure 4. Costa Rican National PES Model for Reforestation. Diagram courtesy of Dr. Herster Barres, Director, Reforest The Tropics, Inc.

The Role of Carbon Markets

It is difficult to estimate the true economic *value* of carbon offsets, which come in all sizes. In the case of carbon sequestration projects, carbon offset prices are not usually realized until the time of sale on the voluntary carbon market. This reality is, in part, attributed to the volatile nature of the voluntary carbon market. Surprisingly, price ambiguity and information asymmetry do not deter emitters from taking part in the market and emitters are willing to pay for carbon sequestration. If Congress were to enact more cap and trade policies to reduce emissions, the value of a carbon offset would theoretically increase by multiple factors.

Companies called brokers list daily price fluctuations and connect buyers to sellers in one transparent and virtual space. Brokers also host auctions to report cleared prices, where purchased offsets are then removed from the market. Although corporations are offsetting their emissions through purchases on the voluntary market, prices remain highly volatile and low (BGC, 2014). Offsets qualify as Kyoto emission reduction mechanisms—usually as CERs. Another class of instruments called Verified Emissions Reductions, or VERs, are comparable to CERs. Namely, companies purchase VERs because they are generated through small-scale projects that do not go through the UN certification process (BCG, 2014). In particular, voluntary demand for carbon offsets increased four percent in 2012 when buyers funneled $523 million into the market to offset 101 million MT of carbon (Ecosystem Marketplace, 2013). Buyers in 2012 paid a volume-weighted average price of $5.9/ton, slightly trailing 2011's $6.2/ton. Whereas the 2011 and 2012 average prices remained low, they were higher than the UN's regulatory offset price, which was less than $1/ton (Ecosystem Marketplace, 2013). Lastly, as governments ratchet down on regulations, the value of carbon is expected to rise.

Leading companies such as Chevrolet offset carbon dioxide, suggesting that companies are trying to actively shape the climate game. Therefore, governments should not underestimate companies' willingness to place a meaningful value on carbon (Ecosystem Marketplace, 2013). Conversely, offset critics posit that the carbon market does not fix the biophysical problem of taking excess carbon dioxide out of the atmosphere via carbon sequestration. As in the case of CDM or REDD, emissions on the carbon market are simply substituted and displaced by one country to another using a voucher-like transaction. In all, the carbon market can place a value on an 'offset,' but what it seldom captures is the value of *carbon sequestration* to society (i.e. what is it worth to society to avoid another five Hurricane Sandys because of reduced parts per million in the atmosphere).

RTT versus the Costa Rica Government PES Program for Reforestation

RTT is capturing its own strain of value by creating ecologically and economically sustainable farm forests. Most foresters will do a 30 percent thinning, compared to RTT's 20 percent thinning, taking more biomass out of forests without the intent of long-term carbon storage. Likewise, it is rare for a forester to thin using a 30 percent rate, let alone a 20 percent one. RTT attempts to ensure that farmers' behavior will follow the RTT ideal through maintaining a strong and long-lasting relationship with the farmer. For example, RTT shares forest growth information, places a sign in the forest designating the sponsor, and meets in person with the farmer to discuss forest management.

Alternatively, since local people in the tropics live off the land, it is important to consider the *opportunity costs* of alternative land uses. Therefore, the Costa Rican government and RTT models are similar in that they try to outcompete the opportunity costs of alternative land uses *for the same person, on the same land, and at the same time*. Thus, the only factors that change the equation are the 'what' (i.e. from *what* is the farmer generating income—forest conservation, cattle ranching?) and 'why' (why is the farmer cattle ranching over planting trees—is she receiving a higher return?) In general, an opportunity cost is defined as the cost of a foregone opportunity. An opportunity cost in the Costa Rican context is what a landowner *could be* earning in lieu of a reforestation project. Therefore, with other factors held equal, a farmer can decide to pursue the Costa Rica PES scheme, RTT's model, *or* a project through REDD/REDD+ as a means to sell carbon on the carbon market. Ultimately, for the cash-strapped landowner, the payoff scheme is what will make her foreclose on one opportunity, and pursue another. Admittedly, these three models must consider *each other* as potential opportunity costs. In this study, the notion of opportunity costs is extended to include *both* forgone profit and 'forgone revenue' because the costs of cattle ranching are estimated, and therefore, forgone profit is, too.

EXPLANATION OF FINANCIAL ANALYSIS

A financial analysis is conducted to demonstrate a value proposition that carbon sequestration provides a valuable return on a farmer's property. Carbon sequestration is defined by a set of distinct biophysical compositions and parameters. The goal of the financial analysis is to create a value proposition that carbon sequestration provides a valuable return using RTT's forests as a base case. In light of the notion of opportunity cost, the financial analysis will take into consideration alternative land uses and the payments for each alternative use. Additionally, the analysis will adopt the perspective of a land owner in Costa Rica, framing each case in a way that illustrates options available to a farmer.

Biophysical carbon sequestration data points are combined with a financial analysis as a way to commodify RTT's *stored* carbon in forests. By starting with raw quantities of sequestered carbon dioxide expressed in metric tons (MT) in RTT's forests and ascribing these quantities different prices of carbon, an overall *value* for stored carbon is calculated. Carbon payments are made on an annual cycle and are a function of biophysical conditions (climate, fertile soil, and natural weather events). Therefore, Scenario A will manipulate biophysical data and highlight tree species and forest management practices employed in RTT's theoretical base case for carbon sequestration. Above all, carbon prices ($/MT) are an important consideration for how to create bona fide carbon products in Scenario C. Similarly, carbon prices can affect the landowner's cash flow, and depending on the price of carbon, alternative land uses can become more appealing to the landowner. RTT's EPICC model, Scenario A, is currently testing a fixed unit price of $5/MT for carbon payments. Next, there is a table comparing Scenario A with capped carbon payments at $2,000 using $5/MT and Scenario B, a hypothetical uncapped EPICC carbon payment plan using different fixed unit prices of carbon. Capped carbon payments in Scenario B refer to a payment ceiling for the amount a farmer can earn from *annual increments* of stored carbon. In Scenario A, there is a $2000 payment ceiling, or cap on carbon payments, for annual increments of stored carbon because of funding limitations.

Eight scenarios are studied based on varying several parameters using an analytical framework. The parameters that are altered to distinguish the scenarios are labeled as followed: **A)** capped carbon payments, **B)** uncapped carbon payments, **C)** different fixed unit prices of carbon, uncapped carbon payments and different fixed unit prices of carbon, **D)** opportunity costs of cattle ranching (revenues and profits), **E)** Costa Rica's PES program, **F)** variable unit prices of carbon, **G)** comparison of NPVs and present values for RTT and competitors, **H)** and the variable costs of carbon, respectively. Since RTT is a base scenario for capped carbon payments at $5/MT up to $2,000, parameters, for example, such as Costa Rica's PES program and uncapped carbon payments are compartmentalized as *variations*. Tables in the Results section each represent a unique scenario that varies a specific parameter.

Scenario Name	Parameter Description	Initial Payment	Annual Payment	Payment/Hectare	Payment/Metric Ton
A	RTT EPICC Base Case+	$2,000	$0-$2976	$34,065 for contract	$5 fixed for contract
B	RTT EPICC Uncapped Carbon Payments at $5/Metric Ton+	$2,000	$150-$3126	$36,085 for contract	$5 fixed for contract
C	RTT Capped and Uncapped Carbon Payments Using Different Carbon Prices	$2,000	Varied based on carbon price (see Table C)	Varied based on carbon price (see Table C)	$3,$7, $5, or $9 fixed for contract
D	Opportunity Costs of Cattle Ranching+	N/A	$0-500	$0-500	N/A
E	Costa Rica's Payments for Ecosystem Services Program (1 ha)+	$980/ha or $1470/ha	$980 or $1470 for 5 years	$980 or $1470 ($1225 average)	$2.73
F	RTT EPICC Uncapped Variable Unit Price of Carbon+	$2,000	N/A	N/A	$5 for years 1-12, $7 for years 13-20 and $9 for years 21-25
G	Comparison of RTT Net Present Values and Present Values of Cattle Ranching and Costa Rica PES+	N/A	Varied based on carbon cap, type of price (fixed or variable) and price of carbon	N/A	Varied (Refer to Scenarios A, B, C, and F)
H	Social Costs of Carbon and California Cap and Trade	N/A	N/A	N/A	Varied (See Table H)

Table 1. Summary Table for Financial Analysis, Scenarios A-H. +Denotes scenarios that incorporate both regular and discounted cash flows. Table letters correspond to Scenario Names. N/A means Not Applicable.

Estimated cattle ranching opportunity costs in Costa Rica are compared to RTT's farmer income data for an entire contract in Scenario D. Comparing the estimated opportunity costs of cattle ranching using three estimated annual averaged costs—$150/ha/year, $300/ha/year and $450/ha/year—represents the landowner's perspective. For the highest opportunity cost of cattle ranching ($500/ha/year), there is a carbon price that gives an identical return to a landowner on the same plot of land. By the same token, a 'break even' carbon price also is calculated. This price is defined as the price of carbon that generates an income that is equal to the income from the highest estimated averaged annual opportunity cost of cattle ranching. It reveals the minimum price of carbon needed to outcompete feasible maximum opportunity costs of cattle ranching. Scenario D features both concepts of opportunity costs specific to this study—forgone revenue in Figure D and forgone profit in Figure D-1.

Because PES programs are expressed in a $/hectare metric, conversions from this metric to a $/MT as in RTT's model is a multi-step process in Scenario E. Also, the analysis will calculate the differences in farmer cash flow through data on carbon using RTT's most recent theoretical data that achieves 40 MT/ha/year in Scenario A. As a result, there will be insight on what the farmer *could make* if the forests achieved this optimal scenario, according to RTT. Furthermore, to more closely match RTT's project scope, the Costa Rica PES program was extended to 25 years, or two PES contracts in Scenario E.

RTT's contract with farmers serves as a base case in Scenario A. That said, adopting the landowner's perspective is imperative to understanding the comparisons and contrasts between the different variations on the base case. To add further richness to the financial analysis, we created a scenario using RTT's EPICC model that does not feature a fixed unit price of $5/MT for the contract duration. Rather, Scenario F will ascribe a variable unit carbon price of $5/MT starting at year 4 until year 12, the year at which carbon payments would be exhausted in Scenario A. Starting in year 13, the unit price of carbon changes to $7/MT until year 20, and then increases to $9/MT from year 21 to 25 to showcase a scenario where RTT incentivizes forest management by conditionally raising carbon prices for the farmer. Consequently, the landowner will have an added consideration for a different financial structure.

The California Cap and Trade Program is also a variation on the financial analysis as part of the variable costs of carbon parameter in Scenario H. Through the California program, avoided greenhouse gas emissions could come from reforestation activities in developing countries. In Scenario H, we hypothetically enroll one of RTT's hectares in the California Cap and Trade Program. In this case, the California Cap and Trade Program is its own stand-alone program. Lastly, firms in the U.S. are ascribing different values to a unit of carbon dioxide. Scenario H will also disclose a few cited prices of carbon for which U.S. firms have been willing to pay in the past year.

Revenues and costs are handled using an accounting approach. Both costs and revenue streams are expressed in both regular and discounted cash flows. The accounting stance pertains to the landowner's perspective only. In the landowner's situation, costs include either five forest thinnings or costs associated with cattle ranching. On the other hand, net present values will be compared between the incoming and outgoing cash flows of cattle ranching and carbon sequestration on an annual basis in Scenario D.

Discount rates are employed to provide sensitivity analysis with respect to the case scenarios. Discount rates are used in the field of environmental economics to account for the time value of money. By doing so, future values are translated into a common present value metric (Traeger, 2009). Essentially, discounting is a way of assessing society's willingness to tradeoff present for future benefits. Discount rates are, therefore, an indispensable key parameter in environment policy-making decisions (NOAA, 2014). Discounting is an interest rate (r) used to derive a net present value (NPV). A NPV is an annualized value calculated by finding the sum of all benefits expressed in present value less the sum of all costs expressed in present value (Traeger, 2009). Discounting postulates that money today is worth more than the same amount of money in the future through the process of compounding with interest (Traeger, 2009). As such, opportunity costs must be considered; if money is not being invested today, it can be put towards something else today.

Analysts usually conduct sensitivity analysis with different interest rates. That said, the financial analysis will utilize a couple different discount rates based on past literature reviews. Cases A, B, D, E and F, however, will use discount rates of 3, 6, and 9 percent to account for a range of rates, and to also account for different weights on future financial flows (refer to Table 1). Specifically, a higher interest rate such as 9 percent will discount the future more heavily and place more weight on the present (Traeger, 2009). In light of these tradeoffs between present and future benefits and costs, choosing an interest rate can be controversial in environmental policy situations (Traeger, 2009). Therefore, the analysis will use one lower-bound discount rate of 3 percent to produce one set of results. Subsequently, the upper-bound discount rate of 9 percent will derive a different set of results. Interestingly, climate economists advocate for an application of mixed discount rates for long-term carbon reduction projects (Traeger, 2009). Therefore, an analysis of descending discount rates is appraised against conventional discounting approaches in Scenario E. A comparison of NPVs for RTT's model and the Costa Rican government program is analogous to the landowner's private decision-making process. Inevitably, farmers need to have a strong understanding of what discounting means for future costs and benefits and how NPVs might affect their decision making processes.

To demonstrate the significance of the financial analysis in this study, RTT might consider sharing the results with potential or interested landowners in Costa Rica. Moreover, one key product that results from this study is a contractual infrastructure that RTT could use as a marketing tool. Having estimated the opportunity costs of cattle ranching associated with its model, RTT could more effectively structure a contract with a landowner. Ideally, RTT could explain this study's results to a landowner and how he should think about carbon sequestration as an overall economically feasible and tangible enterprise in Costa Rica.

Assumptions of Analysis

Costs— In RTT's model, costs can be unreliable for several reasons. In this study, costs proved more difficult to research than benefits and possess a greater degree of uncertainty. Thinning costs are highly varied since farmers are hesitant to do an initial thinning; loggers are notorious for bribing and cheating farmers and landowners in Costa Rica. The relative location of a logged tree to a road can also affect thinning costs. Trees that fall close to roads require very low thinning costs; conversely, logged trees can fall beyond economic hauling distance. Similarly, Costa Rica has very stringent forestry laws, which can deter farmers from thinning for the first time. Thinning costs are calculated using an estimated 30 percent of the lowest priced wood, Ceibo/Chanco, published by the National Forestry Office in Costa Rica (ONF, 2013). In that context, thinning costs are an estimated \$11.86/m^3 for each thinning after converting costs from the Costa Rican colon to the U.S. dollar (1 colon = 0.0018 U.S. dollars, April 2014). Also, the estimated cost of thinning per m^3 is the same for all five thinning periods in RTT's model.

However, the volume of thinnings increases each thinning from year 8 to year 24. Conversely, costs associated with cattle ranching were consulted using literature on deforestation, climate change and RTT. However, according to RTT, a ballpark cost estimate for cattle ranching in the Turrialba region of Costa Rica is $250/ha/year.

Opportunity costs— The opportunity costs of cattle ranching (forgone revenues) in Costa Rica can vary, depending on the purpose for cattle ranching—beef, dairy, or hide—and on the size of the cattle farm. According to RTT, a cattle farmer in the central region of Costa Rica can earn from $0-500/ha/year, hinging on the efficiency of farm operations. Specifically, a farmer of a well-managed and large cattle farm can earn the upper-bound income (around $500/ha/year.) The financial analysis will feature three annual averaged revenues of cattle ranching: $150/year, $300/year, and $450/year to reflect a realistic range of farmer revenues. However, there are other opportunity costs that are not taken into account in this study. For instance, the opportunity costs of growing crops such as bananas, sugar cane, plantains, or coffee, common sources of landowner income in Costa Rica, should not be dismissed altogether. This study acknowledges they exist, but instead focuses on the Costa Rican government model and cattle ranching as the main competitors of RTT's EPICC model. Even though opportunity costs should use a concept of forgone profit only, forgone revenues are an important component in Scenario D because forgone profit was harder to estimate than forgone revenue.

Risks— Growing agricultural products is risky, yet carbon sequestration has its own risks. The risks associated with growing crops are different from forest management, nevertheless. Agriculture has shorter time horizons, and therefore, quicker turnover with returns. The cycles for crops and timber are also not in alignment. A farmer builds up carbon stocks using a layered forest design. Bio-stability is the farmer's hedge against future forest damages. Farmers should be cognizant of biophysical risks: fires, volcanoes, lightening, pests, and decaying trees. Forest design (selection of species), site (soil drainage, previous land use, and rainfall) and forest management (replanting and cleaning) comprise another catalogue of biophysical risks. Alternatively, there are attenuated risks associated with a potential dis-enchanted farmer who either abandons the reforestation contract or skirts his duties as a contracted forest caretaker.

RTT's Model*—**RTT's carbon sequestration data are ***theoretically projected estimates from experimental trials. Actual results will be developed as RTT's research unfolds and as the demonstration forests grow and are properly managed. *For the time being, an optimistic* *scenario is a stand-in for real results that will be confirmed over time.* These biophysical data points also assume a rough one-year recuperation time for trees after a thinning, and thinnings are 14 percent reductions instead of 20 percent. The biological resilience of RTT's forests will be confirmed over time. The use of forest mixtures is likely to determine the level of biological resilience.

RTT's Intellectual Basis of Forests:

1. MT (metric ton of carbon dioxide) is roughly equal to a m^3 (cubic meter) of wood, depending on wood density and the science of carbon sequestration;
2. 20 MT of stored carbon is for the emitter's carbon offsets and 20 m^3 wood is for a farmer to thin, for a total goal of 40 MT/hectare/year of stored carbon, and;
3. a MT CO_2 =CO_2e, where CO_2e is carbon dioxide emissions equivalents

These are assumptions for RTT's carbon sequestration data. These assumptions are also a function of contract enforcement, project verification, and monitoring. RTT contracts a U.S. forestry consultant to conduct audits of its forests and to comment on the value of its applied research. Yet again, due to the research scope of this study, verification and monitoring are not included as ancillary categories of farmer costs.

Basis for farmer income from thinnings are estimated in this study and calculated as following:

1. \$500/year and 20 m^3 going to the farmer for income
2. \$500/year = 20 m^3 * \$/m^3
3. \$500/\$20 = \$25, or **\$25/m^3**

Therefore, the farmer must sell logs at a minimum price of \$25/m^3 to achieve RTT's goal of \$500/hectare/year to the farmer. Trees from older forests produce a higher percentage of commercial wood because of increased growth, which should yield higher prices for thinnings at the tail-end of the RTT contract. Commercial utilization refers to the estimated percentage of a stump that is saleable for commercial use. RTT uses a conservative estimate for prices of wood stumps, or \$55/m^3, which is also the lowest price of a wood stump as indicated by the National Forest Office in Costa Rica (National Forest Office, 2013). Thus, the rationale for using a conservative price for logs is to provide a realistic estimate for farmer thinnings. For example, a high-value species such as Cedar commands $218/m^3 and Pilon, a medium-value species, commands $72/m^3 (National Forest Office, 2013). RTT plants both species in its forests. Therefore, a metric of $55/m^3 is used for all thinnings in Table A-1 because it is a point between $25/m^3 and realistic prices of wood. Commercial utilization is also taken into account in the analysis. Lastly, RTT's base case carbon payments are fixed for the duration of the contract at $5/MT in Scenario A. However, this price is subject to change depending on the compliance and voluntary carbon markets and on new forest plantings and new contracts. RTT uses this price because a) it is the breakeven carbon price for the highest cattle ranching opportunity cost (forgone revenue) b) carbon payments are capped at $2,000 and c) RTT refers to both regulatory and voluntary markets as a reference price. More comparisons of RTT's fixed unit price and other carbon prices will be discussed later.

Scenario A comprises the base case for RTT's new EPICC model. This scenario is instrumental in understanding the relationship between factors linked to the farmer's average income over 25 years. Some longitudinal carbon sequestration data points are 40/MT/ha/year until year 13, and then decrease to 30 MT/ha/year. The important aspect is that these data points are linked together. Achieving 40 MT/ha/year is one of RTT's goals, but it is an optimistic scenario that informs how much money the farmer could theoretically make in an optimal situation. The effects of RTT's actions in the forest are reflected in a farmer's income. This case is also based on the presumption that the forest has a one year recuperation time after each thinning to achieve its year-end accumulated carbon in the previous year. It is also based on a four-year thinning cycle to promote a managed forest. Note that this optimistic case achieves RTT's goal of 500 MT in stored carbon for the emitter over the 25-year contract. Because RTT achieved this goal, finding the price of a carbon offset in its model is calculated as such:

1. RTT receives $7500 from a U.S. carbon emitter for one hectare under EPICC
2. A $7500 donation/500 MT total sequestration = $15/MT for the emitter to balance its emissions in the U.S. over 25 years. In addition, this case achieves RTT's dual goal of $500/ha/year for farmer average income.

On a side note, the forest sequestered an additional 40 MT in year 12. The farmer, therefore, should earn $200 in carbon payments. However, since the payments are capped at $2000, the farmer had already reached $1870, leaving a remainder of $130, which is what he would receive at the end of year 12.

Risks in this model include forest design and selection of species; site (soil, drainage, quality of land after previous land use, climate, rainfall, temperature); forest management (replanting, cleaning, spraying, spaces between plantings, number of seedlings); and other natural factors (lightning strikes, floods, wind, and termites).

The biophysical parameters of this base case scenario are dictated by two types of RTT planting models. The RTT Hi-CO_2 Model uses tree species such as Chancho, Pilon and Klinkii. The Klinkii tree is conducive for long-term carbon storage in forests. Next, the RTT Hi-Value Model takes advantage of trees such as Deglupta, Cedar, Klinkii, and Mahagony. The latter commands a high price of wood, much like Cedar. A combination of these models supports RTT's goals: providing thinning income to the farmer and long-term carbon sequestration. Lastly, a model in development called Sombra! requires a mixture of species such as Botarrama, Mahogony, Maria, Klinkii, and Ocora. As always, RTT management rules apply (i.e. replanting and competitive thinnings).

This model is not perfect, and has natural limitations. Additional considerations and questions include, but are not limited to:

1. What type of forest design could achieve these results?
2. What role does site quality play?
3. What likely real-world factors could affect these results?
4. How to integrate forest management with the Costa Rican farm culture?

Since Scenario A serves as a base case for future parameter considerations, questions about RTT's contract inevitably arise. One consideration is the cap on carbon payments. It is possible that it could be detrimental. For example, a farmer who uses the $2000 pool for carbon payments by the end of year 10 might have less of an incentive to follow proper forest management for the next 15 years, which in turn, would theoretically enhance stored carbon. Also, there may be diminished farmer commitment to 20 percent competitive thinnings. There are eventual implications for this kind of behavior. Moreover, it is important to think of the $2000 cap as either an incentive or a disincentive for a farmer's forest management behavior. The effects of this cap are not yet understood since the EPICC model's results need to be confirmed over time. However, the farmer could abandon the contract once he has reached the price ceiling for carbon payments. More fundamentally, RTT's model must consider the 25-year contract in entirety. Not only will this force landowners to adopt a long-term mindset about the value of forests, but cash flows from stored carbon should theoretically flow farther into the future. The next best option would extend carbon payments to 25 years. That in mind, incentives for long-term carbon storage may not be realized when there is a $2,000 cap on stored carbon, yet RTT is trying to incentivize indefinite carbon storage (100+ years). It is slightly misleading in that carbon is being sequestered for 25 years in the contract, yet payments are capped at the end of year 12.

In an effort to align RTT and farmer incentives, Scenario B will feature uncapped carbon payments at a fixed price of $5/MT for the full-length of the contract. Above all, an uncapped carbon payment parameter at $5/MT will reveal how $2,000 stacks up comparatively. Furthermore, the purpose of an uncapped carbon payment parameter using different prices of carbon ($3/MT, $5/MT, $7/MT, and $9/MT) is to demonstrate how 1) an uncapped model for carbon payments incentivizes good forest management and 2) different prices of carbon are at or above the breakeven carbon price for the opportunity costs of the PES program and cattle ranching. Additionally, prices of $3/MT, $5/MT, $7/MT and $9/MT are utilized in Scenario C based on comparisons of the payments for the Costa Rica PES program and of the $/MT for carbon sold on the voluntary market. A breakdown of the comparison between RTT's $/MT price and the Costa Rica PES $/ha is discussed later in Scenario E.

RTT's original data serves as the core analysis for considering different ways to contextualize carbon prices. Over time, the farmer earns a cash flow from managing the forest as a *carbon sink.* RTT's longitudinal data is collected over time. Longitudinal data is a label for the total annual carbon increments over 25 years minus the volume of thinnings. Furthermore, RTT's metric is expressed on a MT/ha basis. In this case, the metric is 505 MT/ha. After computing this metric, it is inverted to express a hectare/MT metric. On the other hand, Costa Rica's PES program is expressed using a $/ha metric. Using an average for landowners who plant native and non-native species, the metric is $1225/ha. The dimensional analysis to back out an implicit dollar amount ($/MT) for sequestration is

($1,225/ha) * (ha/505 MT)

Hectares cancel out, and thus, **$1,225/505 MT = $2.43/MT.**

As a way to contextualize carbon prices, RTT should use *at least* a $2.43 carbon price in order to compete with Costa Rica's PES program. Because RTT is currently giving the farmer $5/MT, carbon sequestration is a financially viable enterprise for the farmer relative to the PES program. One consideration is that the PES program is structured as a short program (15-20 years) relative to RTT. Therefore, the PES program is extended to two contracts for this to be a useful comparison. Even if the farmer were to receive the lowest $/MT in Table E, $3/ton, the farmer is receiving a healthy return relative to the PES scheme.

RESULTS

SCENARIO A (RTT EPICC Model Base Case)

End of yr	**Growth rate/yr**	**Yr end accumulated carbon in forest MT/CO_2e before thinnings**	**Yr end volume after thinning 1 m^3= 1 MT CO_2e**	**% thin**	**Volume of thinning (m^3)**	**Carbon payments @ $5/MT up to $2,000 starting at year 4**	**Value of thinning (see Table 1)**	**Model initial $2,000 grant, carbon payments and thinnings**	**Accumulated income**
1	5	5						$1000	$1000
2	19	24						$500	$1500
3	35	59						$500	$2000
4	40	99				$495		$495	$2495
5	40	139				$200		$200	$2695
6	40	179				$200		$200	$2895
7	40	219				$200		$200	$3095
8, thin	40	259	223	14%	36	$200	$798	$998	$4093
9	35	258				$175		$175	$4268
10	40	298				$200		$200	$4468
11	40	338				$200		$200	$4668
12, thin	40	378	325	14%	53	**$130 (carbon payments end, reach $2,000)**	$1745	$1875	$6543
13	30	355						$0	$6543
14	30	385						$0	$6543
15	30	415						$0	$6543
16, thin	30	445	383	14%	62		$2398	$2398	$8941
17	30	413						$0	$8941
18	30	443						$0	$8941

19	30	473						$0	$8941
20, thin	30	503	432	14%	70		$2709	$2709	$11,650
21	30	462						$0	$11,650
22	30	492						$0	$11,650
23	30	522						$0	$11,650
24, thin	30	552	475	14%	77		$2976	$2976	$14,626
25	30	505				$0		$0	$14,626
Total	**804**	**505**			**299**	**$2,000**	**$10,626**	**$14,626**	**$14,626**
Grant $ and CO_2 pay-ments								**$4,000**	
Avg annual income								**$585.04**	
Total income								**$34,065**	
+Theor-etical avg income								**$1363**	
	100%	**63%**			**37%**				**% thin = 14**

+Theoretical income is higher than average annual income because it includes the final asset of thinning (see Table A-3 below).

Table A. Reforest The Tropics-Superior Nut Company and Bresnan Donor Forest in Costa Rica as a Base Case. Latest theoretical version of RTT's EPICC Model. Data subject to change according to the actual results of the research plots. The first carbon payment at $5/MT is based on a starting aggregate annual increment of 99 MT CO_2e (years 1-4 combined). Data courtesy of Dr. Herster Barres, Director, Reforest The Tropics, Inc. Author, H. Barres. Verified 13 March 2014. info@reforestthetropics.org

# Thinning	Estimated m^3 of timber for thinnings	Estimated avg wood $ price on the stump*	Estimated commercial utilization**	Total Value	Cost of Thinning
1	36	55	40	$798	$427
2	53	55	60	$1745	$629
3	62	55	70	$2398	$735
4	70	55	70	$2709	$830
5	77	55	70	$2976	$913

Total value of thinnings				**$10,626**	
Asset value year 25	**505**	**55**	**70%**	**$19,439**	
TOTAL (Thins + Final Asset)	*2013 National Forest Office Stumpage Price.	**Estimated percent of the stem that is commercial for sale.		**$30,065**	

Table A-1. RTT EPICC Model Farmer Estimated Thinning Revenue and Cost Estimates—SUBJECT TO CONFIRMATION. To calculate the value of the first thinning, for example, 36 m^3 * $55/$m^3$ *.40 commercial utilization = $792. This table also applies to all variations of RTT's base case. Data courtesy of Dr. Herster Barres, Director, Reforest The Tropics, Inc. Author H. Barres. Verified 13 March 2014. info@reforetthetropics.org

Total Estimated Farmer Income	
Initial Grant	$2,000
Carbon Payments (Payment Ceiling)	$2,000
Thins + Final Asset*	$30,065
TOTAL	**$34,065**
Avg income/ha/yr (25 yrs)	$1,363
+CO_2 Payments	$5/MT
+MT captured in last year. Price is fixed for contract period.	*Final asset is the estimated *end* value of thinnings (505 MT CO_2e 25 year-end accumulated carbon in forest * $55/$m^3$ *.70 commercial utilization =$19,439.)

Table A-2. Total Estimated Farmer Income over 25-Year RTT EPICC Contract. Data courtesy of Dr. Herster Barres, Director, Reforest The Tropics, Inc. Author, H. Barres. Verified 13 March 2014. info@reforestthetropics.org

Discount Rate	r =.03 (3%)	r =.06 (6%)	r =.09 (9%)
Present Value of Benefits (grant, carbon payments, thinnings, and final asset)	**$19,115**	**$11,555**	**$7562**
Present Value of Costs (five thinnings)	**$2145**	**$1354**	**$887**
Net Present Value (NPV) for Entire Contract	**$16,970**	**$10,201**	**$6675**
Appropriateness of Discount Rate in Terms of NPV	**1**	**2**	**3**

Table A-3. Comparison of NPVs Using Three Discount Rates for Base Case RTT EPICC Model at $5/MT. All values are rounded to nearest whole dollar. Rank is based on the descending value of NPV. Discount rates of 3, 6 and 9 percent are used because they reflect common interest rates employed in past climate policies, according to Traegar (2009).

SCENARIO B (RTT EPICC Uncapped Carbon Payments at Fixed Unit Price of $5/MT)

End of Yr	Growth rate/yr	Yr end carbon in forest	Yr end volume	% thin	Volume thinnings	Carbon payments	Value of thinnings	Model	Accumulated income
1	5	5						$1,000	$1000
2	19	24						$500	$1500
3	35	59						$500	$2000
4	40	99				$495		$495	$2495
5	40	139				$200		$200	$2695
6	40	179				$200		$200	$2895
7	40	219				$200		$200	$3095
8, thin	40	259	223	14%	36	$200	$798	$998	$4093
9	35	258				$175		$175	$4268
10	40	298				$200		$200	$4468
11	40	338				$200		$200	$4668
12, thin	40	378	325	14%	53	***$200***	$1745	**$1945**	**$6613**
13	30	355				***$150***		**$150**	**$6763**

14	30	385				***$150***		**$150**	**$6913**
15	30	415				***$150***		**$150**	**$7063**
16, thin	30	445	383	14%	62	***$150***	$2398	**$2548**	**$9611**
17	30	413				***$150***		**$150**	**$9761**
18	30	443				***$150***		**$150**	**$9911**
19	30	473				***$150***		**$150**	**$10061**
20, thin	30	503	432	14%	70	***$150***	$2709	**$2859**	**$12920**
21	30	462				***$150***		**$150**	**$13070**
22	30	492				***$150***		**$150**	**$13220**
23	30	522				***$150***		**$150**	**$13370**
24, thin	30	552	475	14%	77	***$150***	$2976	**$3126**	**$16496**
25	30	505				***$150***		**$150**	**$16646**
Total	**804**	**505**			**299**	**$4020**	**$10,626**	**$16,646**	
Farmer grant $ and carbon payments								**$6020**	
Avg. annual income								**$666**	
Total income								**$36,085**	
Theoretical avg income								**$1443**	
	100%	**63%**			**37%**				**% thin = 14**

Table B. Reforest The Tropics-Superior Nut Company and Bresnan Donor Forest in Costa Rica Using an Unlimited Cap at Fixed Unit Price of $5/MT for Carbon Payments. Note: Revenues from thinning estimates are the same as the baseline case (see Table A-1 above). Bold and italicized values indicate carbon payments that have been added on top of the base case. Original data courtesy of Dr. Herster Barres, Director, Reforest The Tropics, Inc. info@reforesthetropics.org

Total Adjusted Estimated Farmer Income	
Initial Grant	$2000
Carbon Payments	$4020
Thins and Final Asset	$30,065
TOTAL	**$36,085**
Avg. Income/ha/yr (25 yrs)	$1443
+CO_2 Payments	$5/MT
+MT captured in last year. Price is fixed for contract period.	

Table B-1. Adjusted Total Estimated Farmer Income with No Carbon Payment Cap.

Discount Rate	**r =.03 (3%)**	**r =.06 (6%)**	**r =.09 (9%)**
Present Value of Benefits (grant, carbon payments, thinnings and final asset)	**$20,283**	**$12,250**	**$7986**
Present Value of Costs (five thinnings)	**$2145**	**$1354**	**$887**
Net Present Value (NPV) for Entire Contract	**$18,138**	**$10,896**	**$7099**
Appropriateness of Discount Rate in Terms of NPV	**1**	**2**	**3**

Table B-2. Comparison of NPVs Using Three Discount Rates for RTT EPICC Model UNCAPPED at $5/MT. All values are rounded to nearest whole dollar. Rank is based on the descending value of NPV.

SCENARIO C (RTT Capped and Uncapped Different Fixed Unit Prices of Carbon)

Year End	**Annual Increment (MT) CO_2e**	**$3/MT**	**$5/MT (base case)**	**$7/MT**	**$9/MT**
1	5	$1,000	$1,000	$1,000	$1,000
2	19	$500	$500	$500	$500
3	35	$500	$500	$500	$500
4	40	$297	$495	$693	$891
5	40	$120	$200	$280	$360
6	40	$120	$200	$280	$360
7	40	$120	$200	$280	***$360***
8	40	$120	$200	***$280***	$360
9	35	$105	$175	$245	$315
10	40	$120	$200	$280	$360
11	40	$120	***$200***	$280	$360
12	40	$120	$200	$280	$360
13	30	$90	$150	$210	$270
14	30	$90	$150	$210	$270
15	30	$90	$150	$210	$270
16	30	$90	$150	$210	$270
17	30	$90	$150	$210	$270
18	30	$90	$150	$210	$270

19	30	$90	$150	$210	$270
20	30	***$90***	$150	$210	$270
21	30	$90	$150	$210	$270
22	30	$90	$150	$210	$270
23	30	$90	$150	$210	$270
24	30	$90	$150	$210	$270
25	30	$90	$150	$210	$270
Grant $ and Carbon Payments		**$4412**	**$6020**	**$7628**	**$9236**
Avg. income		**$602**	**$666**	**$730**	**$794**
Total income		**$34,477**	**$36,085**	**$37,693**	**$39,301**
Theoretical avg. income		**$1379**	**$1443**	**$1508**	**$1572**

Table C. Commodification of Carbon Dioxide: Merging Biophysical Data and Prices as an Inter-temporal Analysis. Annual streams of revenues associated with carbon storage and sequestration were calculated utilizing different carbon prices and biophysical quantities as components. Bold and italicized values indicate the last payment for each price of carbon if there were a payment cap of $2000.

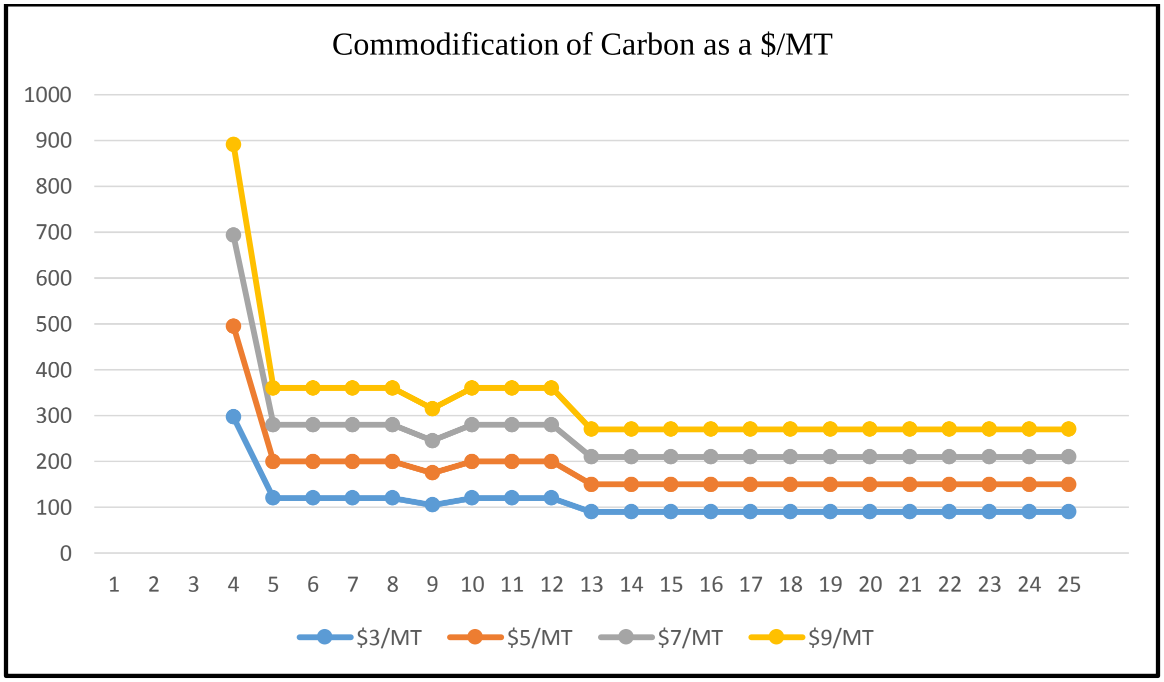
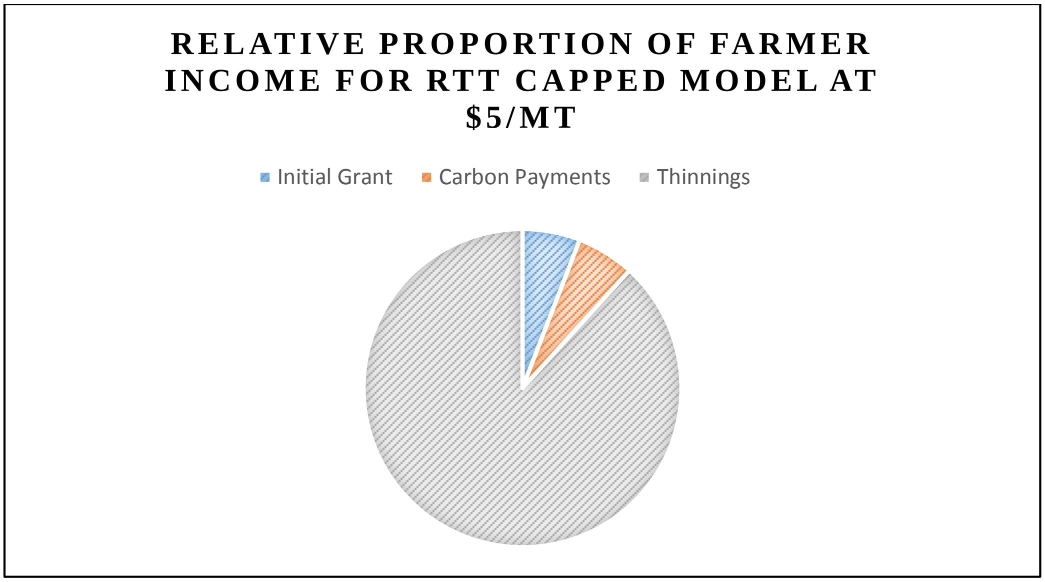


Figure C-1. A Visual Representation of the Future Benefits from Carbon Payments. X-axis indicates years and Y-axis indicates dollars.



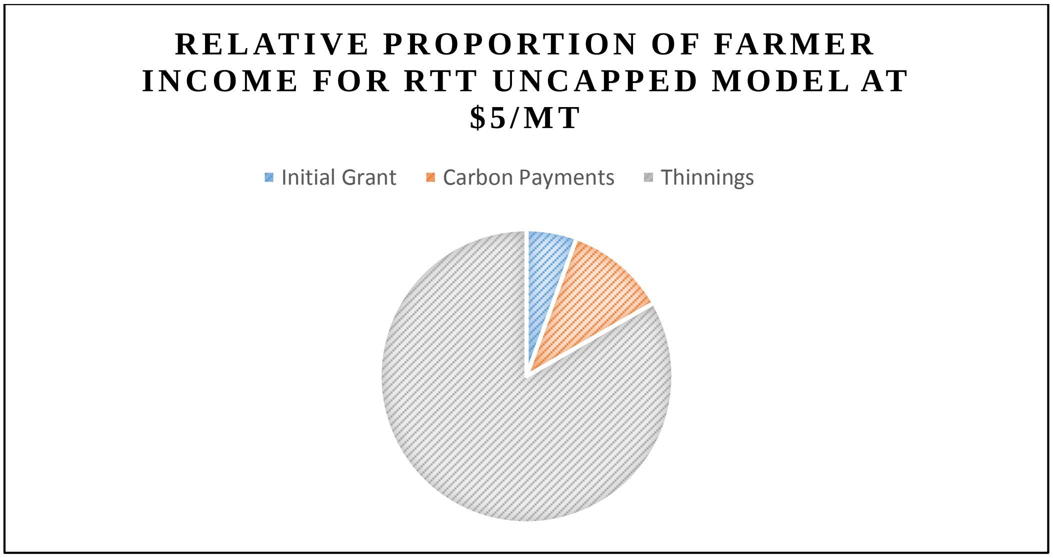


Figure C-2 and C-3. Comparisons of Relative Farmer Income between Capped and Uncapped RTT EPICC Model at $5/MT.

SCENARIO D (Opportunity Costs of Cattle Ranching in Terms of Forgone Revenue and Profit)

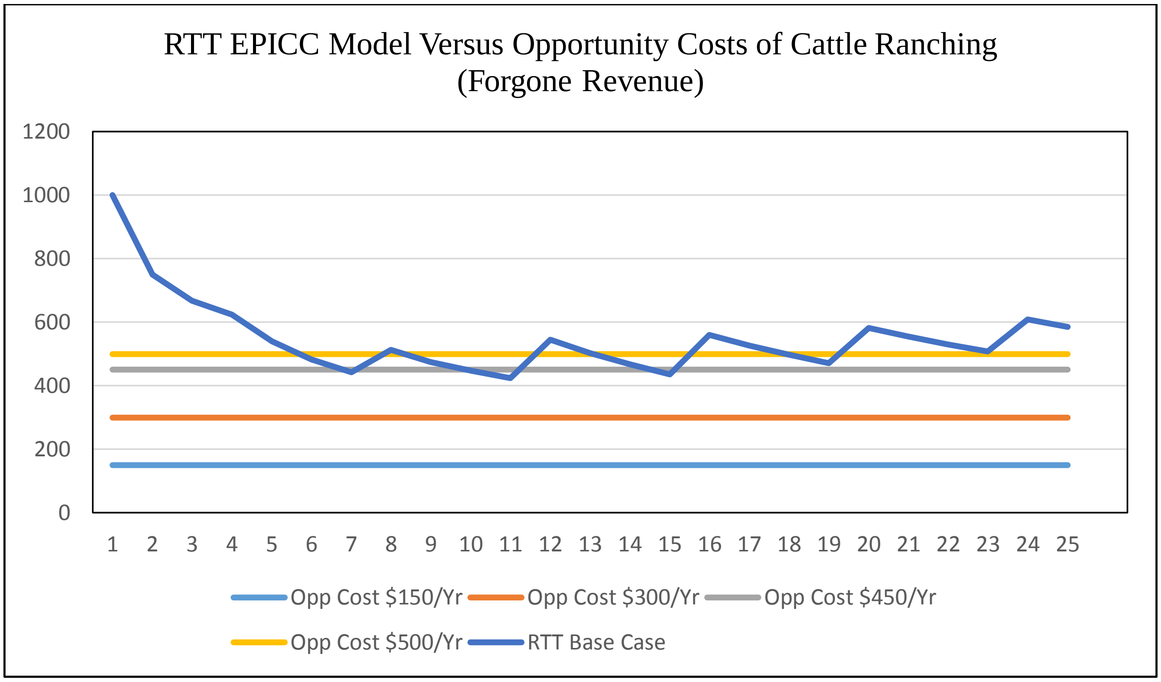


Figure D. Opportunity Costs of Cattle Ranching (Forgone Revenue) Versus RTT's Base Case at $5/MT. X-axis indicates years and Y-axis indicates average annual dollar amounts. Revenues for RTT and cattle ranching are *averaged annual incomes* over 25 years. For RTT to outcompete the opportunity costs of cattle ranching, average farmer income must be higher than $500/ha/year, the optimal revenue scenario for a cattle rancher. A price of $5/MT is the 'breakeven' carbon price at which the highest known opportunity costs of cattle ranching is roughly equal to RTT's average farmer income over 25 years.

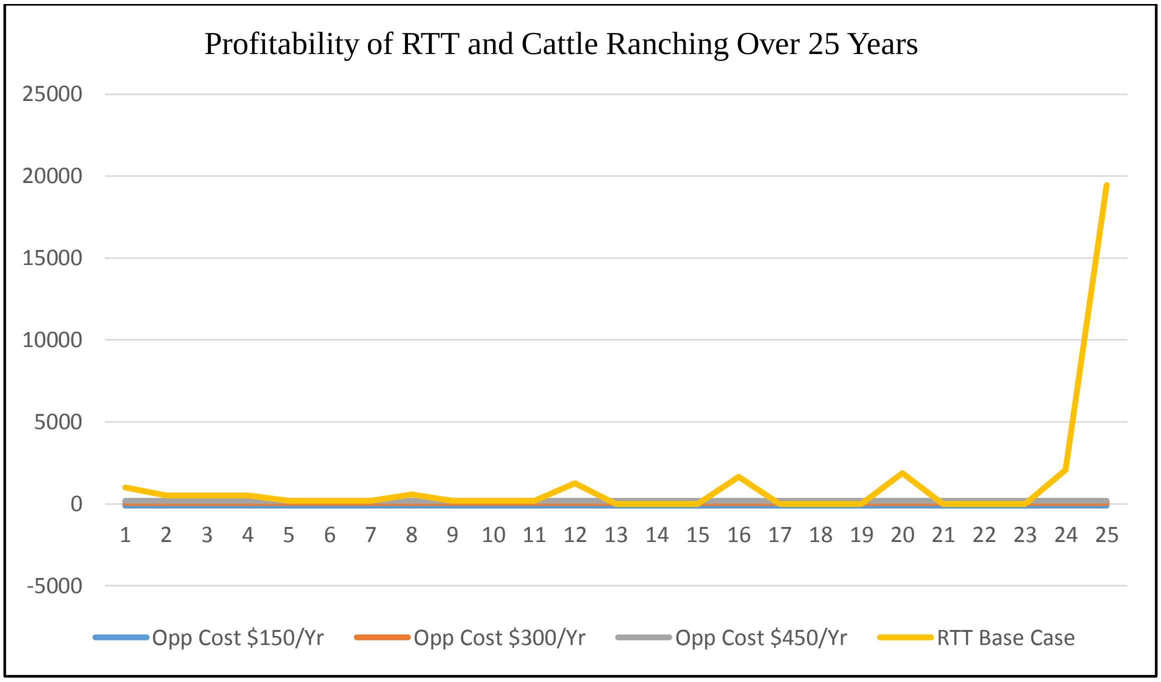


Figure D-1. RTT and Cattle Ranching (Profitability) Opportunity Costs Over 25 Years. X-axis indicates years and Y-axis indicates overall 25-year profitability. Profitability for RTT was calculated by subtracting thinning costs from thinning income for years 8, 12, 16, 20 and 24. Cattle ranching profitability was calculated by subtracting a cost of $250/year from the three estimated annual averaged opportunity costs (forgone revenue). A price of $5/MT is RTT's breakeven carbon price to compete with the highest opportunity cost of cattle ranching (forgone revenue).

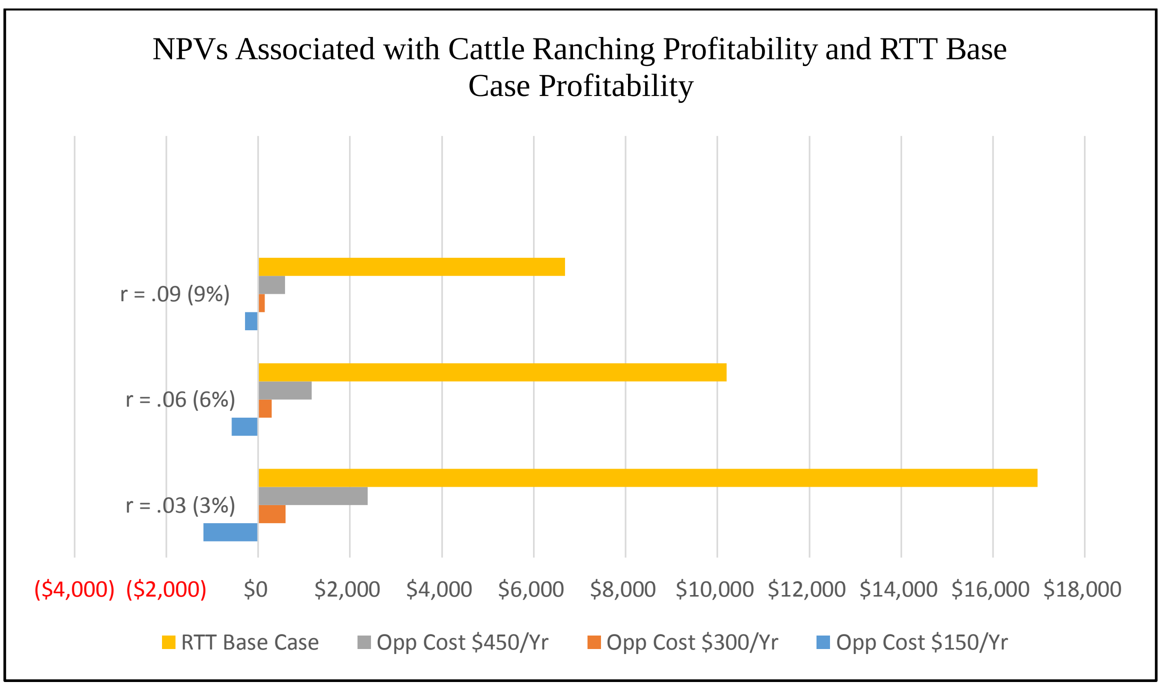


Figure D-3. NPVs of RTT Base Case Profitability and Three Annualized Averaged Opportunity Costs of Cattle Ranching Using Three Discount Rates. Numbers in red indicate negative NPVs.

SCENARIO E (Costa Rica's PES Program)

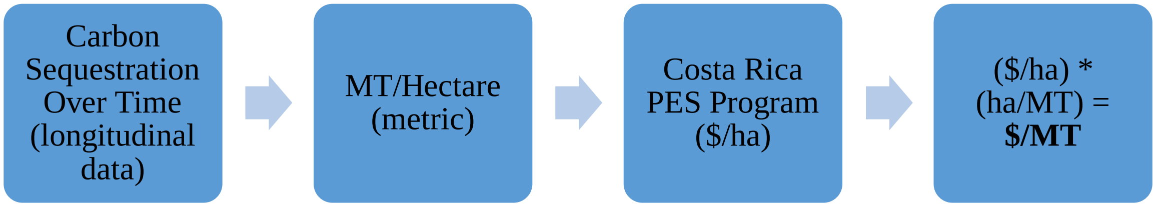


Figure E. Ways to Contextualize CO_2 Prices. Carbon sold into compliance carbon markets, such as the California Carbon Cap and Trade Program, is expressed as a $/MT. Carbon sold into a voluntary market via a PES program is expressed in hectare form as a $/hectare. Carbon units expressed in MT/ha will be converted to a $/MT metric.

Year	**Non-native species $/ha**	**Native species $/ha**	**RTT capped $5/MT**	**RTT capped $3/MT**
1	$980	$1470	$1000	$1,000
2	$980	$1470	$500	$500
3	$980	$1470	$500	$500
4	$980	$1470	$495	$297
5	$980	$1470	$200	$120
6	--	--	$200	$120
7	--	--	$200	$120
8, thin	--	--	$998	$918
9	--	--	$175	$105
10	--	--	$200	$120
11	--	--	$200	$120
12, thin	--	--	$1875	$1865

13	--	--	--	$90
14	--	--	--	$90
15	--	--	--	$90
16, thin	$980	$1470	$2398	$2488
17	$980	$1470	--	$90
18	$980	$1470	--	$90
19	$980	$1470	--	$90
20, thin	$980	$1470	$2709	$2799
21	--	--	--	$38
22	--	--	--	--
23	--	--	--	--
24, thin	--	--	$2976	$2976
25	--	--	$19,439	$19,439
Total income for (2) 1-ha government contracts, (1) RTT contract	**$9800**	**$14,700**	**$34,065**	**$34,065**
Present Value, r =.03 (3%)	**$7369**	**$11,053**	**$19,115**	**$18,960**
Present Value, r =.06 (6%)	**$5851**	**$8776**	**$11,555**	**$11,335**
Present Value, r =0.9 (9%)	**$4858**	**$7288**	**$7562**	**$7320**
Present Value, r = 5% for 10 years, 4% for 10 years and 3% for 5 years (descending discount rates)	**$6665**	**$9998**	**$18,170**	**$18,293**

Table E. A Cash Flow and Discounted Cash Flow Comparison of RTT Capped Model for $5/MT (base case) and $3/MT (calculated price for PES sequestration) to Costa Rica PES Program for Non-Native and Native Species Extended to 25 Years. Since Costa Rica's PES program costs are not considered, only benefits are projected. Dashes represent years without landowner income. Prices of $3/MT and $5/MT are used because $5/MT is RTT's current base case price and $3/MT is the Costa Rica PES program $/MT. *Source for descending discount rates: Weitzman, 2001.*

SCENARIO F (RTT EPICC Different Variable Unit Prices of Carbon)

End of yr	**Growth rate/yr**	**Yr end accumulated carbon in forest MT/CO_2e before thinnings**	**Yr end volume after thinning 1 m^3= 1 MT CO_2e**	**% thin**	**Volume of thinning (m^3)**	**Carbon payments @ $5/MT up to $2,000 starting at year 4**	**Value of thinning (see Table 1)**	**Model initial $2,000 grant, carbon payments and thinnings**	**Accumulated income**
1	5	5						$1000	$1000
2	19	24						$500	$1500
3	35	59						$500	$2000
4	40	99				$495		$495	$2495
5	40	139				$200		$200	$2695
6	40	179				$200		$200	$2895
7	40	219				$200		$200	$3095
8, thin	40	259	223	14%	36	$200	$798	$998	$4093
9	35	258				$175		$175	$4268
10	40	298				$200		$200	$4468
11	40	338				$200		$200	$4668
12, thin	40	378	325	14%	53	$200	$1745	$1945	$6613
13	30	355				$210		$210	$6823
14	30	385				$210		$210	$7033
15	30	415				$210		$210	$7243
16, thin	30	445	383	14%	62	$210	$2398	$2608	$9851
17	30	413				$210		$210	$10,061
18	30	443				$210		$210	$10,271
19	30	473				$210		$210	$10,481
20, thin	30	503	432	14%	70	$210	$2709	$2919	$13,400
21	30	462				$270		$270	$13,670
22	30	492				$270		$270	$13,940
23	30	522				$270		$270	$14,210
24, thin	30	552	475	14%	77	$270	$2976	$3246	$17,456
25	30	505				$270		$270	$17,726
Total	**804**	**505**			**299**	**$5100**	**$10,626**	**$17,726**	

Grant $ and CO_2 payments								**$7100**	
Avg annual income								**$709**	
Total income								**$37,165**	
Theor-etical avg income								**$1,487**	
	100%	**63%**			**37%**				**% thin = 14**
NPV, r = .03 (3%)								**$18,738**	
NPV, r = .06 (6%)								**$11,239**	
NPV, r = .09 (9%)								**$7300**	

Table F. Variable Prices of Carbon for RTT EPICC Model. A price of $5/MT is for years 4-12, $7/MT for years 13-20 and $9/MT for years 21-25.

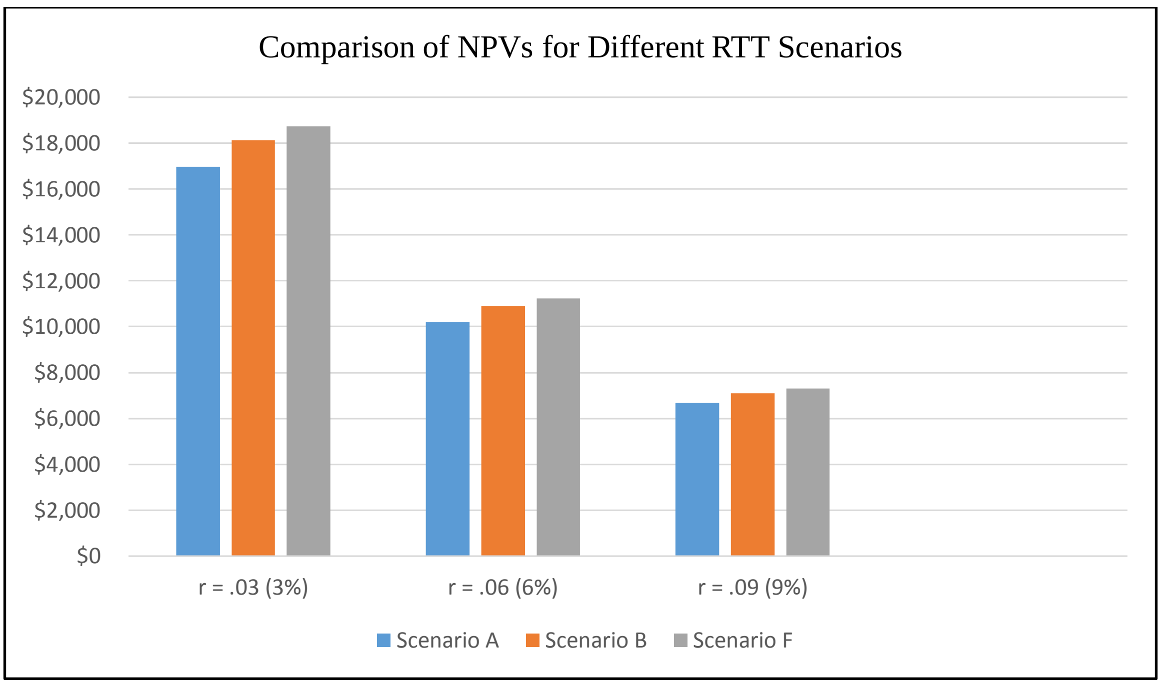


Figure G. Comparisons of NPVs for Variations on RTT Base Case.

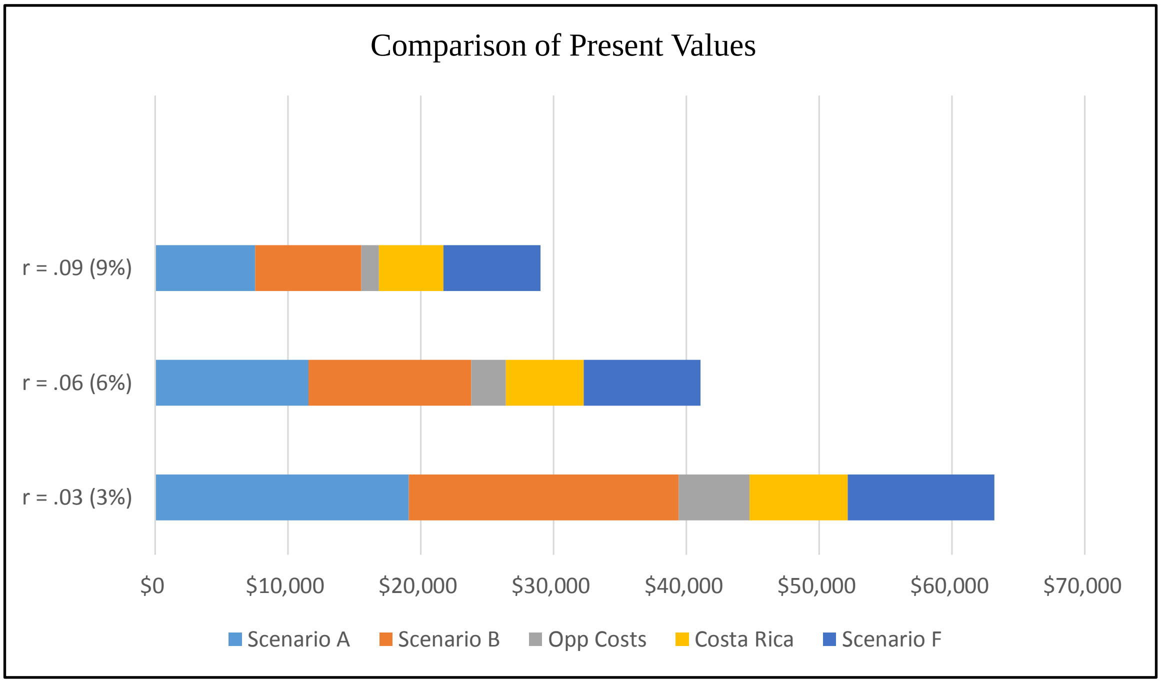


Figure G-1. Comparison of Present Values across RTT Contract Variations, Opportunity Costs of Cattle Ranching and Costa Rica's PES Program.

Firm	Carbon Price+
Exxon Mobil	$60/ton
Obama Administration	$37/ton++
Disney	$11-14/ton
California Cap and Trade	**$11.50/ton**
Google	$11/ton
EU	$6.70/ton
Microsoft	$6-7/ton
RTT	**$15/MT+**

+The variations on carbon price are ascribed to a ton of carbon for each firm's planning purposes. RTT's carbon price represents the cost to offset a MT of carbon through the EPICC model. ++Obama Administration's entry is most likely closer to the 'social cost of carbon.'

Table H. Internal Costs of Carbon and California Cap and Trade Program. If RTT farmers sold offsets in California's Cap and Trade scheme, they would earn $11.50/ton CO_2e. A MT is roughly 10 percent more than a ton of CO_2e (MT= 1.1023 tons). Therefore, a farmer could sell 505 MT (556.66 tons) * $11.50/ton for a total of $6,402. *Source: European Union Emissions Trading System 2013.*

CHALLENGES AND LIMITATIONS

This study does not take into account multiple categories of realistic costs, including, but not limited to: project transaction costs, monitoring costs, third-party verification costs and Costa Rica PES costs. Actual RTT thinning costs were not obtained on a landowner case-by-case basis, which is likely the most accurate estimate of thinning costs, according to RTT. Although these costs are not included in this study for pragmatic reasons, they exhibit important tradeoffs with landowner benefits that should be considered in future studies. Additionally, the costs of the PES reforestation program in Costa Rica are not within the research bounds of this study. More in depth-studies should incorporate these costs to the best of their ability in order to provide more accurate discounted cost cash flows and NPVs. Theoretically, NPVs should be lower in this study because these costs were not taken into account. That said, this study does not estimate benefit-cost ratios for NPVs because benefits exceed costs by multiple factors.

Neither current nor potentially contracted farmers for RTT's model were consulted or interviewed, which could have provided a human behavioral component to the study. Farmer interviews are critical to understanding their wants and needs as working landowners in developing contexts and understanding their ways of valuing ecosystem services and ancillary environmental and social benefits. Future studies should capitalize on this opportunity for these reasons.

RTT's values are theoretical at this point in time. As with any theoretical data, RTT might find a way to disclose more exact and accurate information in the future. While biophysical carbon data points could be generous overestimates, at least they demonstrate what an optimal situation would resemble for both RTT and the farmer, meanwhile the science and technology of forest management progresses.

CONCLUSIONS

Carbon sequestration and commodification in economic farm forests in Costa Rica must create value for landowners as a result of a financially compelling value proposition. Ultimately, a landowner will consider the *best*—or most profitable—use of her land from a private decision-making perspective. Using similar comparisons, the landowner can weigh profits from forestry against profits from cattle ranching or Costa Rica's PES program. The landowner's financial perspective of forestry, cattle ranching, and PES projects is a useful analytical framework for thinking about the benefits and costs associated with each scenario. Furthermore, the nexus between degrading land use activities such as cattle ranching, greenhouse gas emissions, and climate change is very strong. On the other hand, volatility in the carbon markets results in buyer uncertainty, which affects market prices of carbon. The value of offsets aside, carbon sequestration and commodification enables landowners to reap economic benefits from managing forests as a carbon dioxide sink. From a biophysical standpoint, it takes carbon dioxide out of the atmosphere, which is important for lowering atmospheric ppm.

In the future, stored carbon in forest biomass may take on an economic value that is greater than the same trees sold as logs. Ultimately, the commodification of carbon has the potential to drive a wide wedge between the value of stored carbon and the value of alternative land uses. Above all, it is important that carbon sequestration and commodification make the financial case for a landowner to forgo degrading land uses. At the least, reforestation must fully compensate for the highest competing opportunity cost. As soon as carbon commodification and sequestration *outcompetes* the highest competing opportunity cost, the notion of opportunity costs represents an economic loss to the landowner. Consequently, the landowner will preclude land degrading activities by virtue of pursuing economic farm forestry. Nonetheless, a confluence of these factors could enable a transition from land degrading activities to reforestation as a viable enterprise, which could be a pivotal point in climate policy decision making across the globe.

Each case scenario, A-H, represents a discernible core product of the financial analysis by packaging these eight scenarios and changing different parameters. Although it is difficult to understand where RTT fits in the larger picture of carbon markets or Costa Rica's 2021 Carbon Neutrality goal, uncapped versus capped carbon payment parameters and different prices of carbon are important considerations for the EPICC model. Questions about a carbon cap and the timing and frequency of economic returns in RTT's base case are crucial considerations for the landowner. The discount rate at which the private landowner will tradeoff present earnings versus future earnings or, alternatively, the rate at which the landowner could borrow money at a bank is an appropriate way to choose a discount rate. The latter is perhaps the most appropriate perspective on discount rates for this study.

In Scenario B, the farmer could earn an extra $2020 from carbon payments alone with no payment cap at $5/MT. This value is more than double what he would receive from carbon payments in RTT's base case. In this scenario, the farmer has no limbo year whereby he earns

$0 in income. Every year of the 25-year contract the farmer is earning income, the least of which is $150/year between years of income from thinnings. When comparing the NPVs between RTT's base case and Scenario B, the largest difference between NPVs, $1168, results from using a discount rate of 3 percent. If RTT were to compare the NPVs of Scenarios A and B, it must consider, once again, how a private landowner will choose to either tradeoff present earnings for future earnings or how the private landowner is able to borrow funds at a given rate.

For Scenario C, different fixed prices of carbon are dollar coefficients that affect cash flow. In the case of $3/MT, $2,000 is used more slowly. Conversely, a price of $9/MT uses the $2,000 cap quickly. Therefore, the price of carbon would still have an impact on cash flow if there was a $2000 price cap on carbon payments. However, because the cap limits farmer cash flow from carbon payments, its impact is also limited. The role of a carbon price when there is a cap on carbon payments is a matter of how quickly the farmer receives $2000. A farmer who earns $2000 in the first half of the contract might consider opportunity costs due to lack of financial incentive from carbon payments during the second half. Notably, a price of $9/MT for the $2000 cap is exhausted in year 7, whereas a price of $7/MT is exhausted in year 8. With only a one year difference between the exhaustion of dollar coefficients $7/MT and $9/MT, it probably will not make a difference to the farmer which price RTT ascribes to carbon. On the other hand, $3/MT and $5/MT are exhausted in year 11 and 20, respectively. The difference in years between these two coefficients is 9. Therefore, a price of $3/MT versus a price of $5/MT could potentially make a difference to a landowner in terms of years without economic return. Alternatively, the landowner could think of these dollar coefficients as raising his average annual income $64 per $2 increase in MT price in an uncapped situation.

Cattle ranching is one of RTT's biggest competitors. It is also a barrier to entry with respect to reforestation projects. In Scenario D, by estimating the opportunity costs of both forgone revenue and forgone profit and NPVs associated with cattle ranching in a tabular form, RTT can visually understand under what financial conditions cattle ranching poses a competitive threat to reforestation projects. In regard to the forgone revenue comparison between estimated averaged annual opportunity costs of cattle ranching and RTT's annual farmer income using its base case, RTT average farmer income falls below the $450/year opportunity cost threshold three times and falls below the $500/year opportunity costs 9 times. Undoubtedly, either increased dollar coefficients for carbon payments, no cap on carbon payments or a combination thereof would provide a financial cushion between RTT farmer average income and the highest thresholds of cattle ranching opportunity costs. Likewise, when visually viewing the profitability and NPVs associated with RTT's base case, there is no considerable comparison between cattle ranching and its base case. The area in which RTT could improve is raising average annual farmer income, as that is a more common metric comparison between the base case and opportunity costs of cattle ranching for forgone revenues. As seen in Scenario C, raising the dollar coefficient of carbon $2/MT increases farmer average income by $64 with no carbon payment cap.

Cost Rica's reforestation PES Program is a recent competitor to RTT's base case, especially with the government's new Carbon Neutrality goal. In this scenario, discount rates affect the difference between present values of RTT and the PES Program in important ways. First, the descending discount rates approach results in the second highest present value next to 3 percent for all four considerations—two PES and two RTT. On average, they are a difference of $873 from the 3 percent approach, with the capped $3/MT consideration as the smallest difference. Markedly, a 3 percent discount rate is suitable when comparing a $1470/ha PES payment and RTT base case at $5/MT. With a 9 percent discount rate, the difference in present value between the two consideration is the smallest, or $274, which makes PES more competitive with RTT's base case. Conversely, a 3 percent discount rate results in the highest difference between present values, or $8062. A descending discount approach is only $110 off, with a difference of $8172, implying it is also a suitable discounting approach. Lastly, a 3 percent discount rate and descending discount rates drive a larger wedge between the present values of the $1470/ha PES and RTT base case, undermining the competition.

Ultimately, the highest NPV of any RTT base case variation is Scenario F, different variable prices of carbon using a 3 percent discount rate. However, this NPV is only $500 more than Scenario B, RTT Uncapped at $5/MT. A comparison of NPVs between Scenarios B and F using a 9 percent discount rate yields a $201 difference, less than half the difference using 3 percent. To compare these, a 3 percent discount rate widens the gap in NPV difference. In Scenario G, it is visually evident that a 9 percent discount rate levels the differences between NPVs of RTT's base case variations, namely Scenarios A, B, and F. Furthermore, present values of Costa Rica's PES program are higher than those of cattle ranching.

If RTT were to enroll one if its hectares in California's Cap and Trade Program, the landowner could potentially earn $6402. To put this in perspective, the earning is roughly equal to the $6020 amount a farmer could receive from the initial grant and carbon payments *alone* in Scenario B, uncapped carbon payments at a fixed price of $5/MT. Moreover, firms belonging to the same industry, such as Google and Microsoft, are valuing a unit of carbon differently. This suggests firms not only have conflicting valuation methods, but they are not equally capturing the burden they are putting on society through a cost of carbon.

Discount rates matter when considering tradeoffs between past and future benefits. In RTT's case, discount rates are important. Particularly, the interest rate at which a Costa Rican landowner is able to borrow funds is the most appropriate application of discount rates in this study. It is the perspective of a private financial analysis.

RTT should structure a contract for a potential landowner that is contingent on carbon prices and on profitability comparisons to cattle ranching or Costa Rica's PES program. Specifically, RTT's new EPICC model is a financial platform that shares the value of stored carbon in forests with a landowner. Not only does RTT pose a way for emitters to offset their emissions in the U.S., it makes a case for carbon sequestration in tropical farm forests. RTT's model for sequestration makes reforestation a two-in-one package: theoretical carbon offsets for the emitter and long-term carbon sequestration for climate change. By that knowledge, RTT should continue to justify its cause to procure future funding. When disclosing the opportunity costs of cattle ranching to a potential landowner, RTT should focus on farmer *theoretical* average income over 25 years to overcompensate for the highest opportunity costs of cattle ranching, or forgone revenue. This delineation should be a major component of RTT's contract to a landowner. Most of all, if RTT were to have an adequate amount of funding, it should consider Scenario B, uncapped carbon payments at $5/MT. A cap on carbon payments is a financial detriment to the landowner. With increased donations from U.S. emitters, RTT could pay farmers a fixed unit or variable unit price of carbon for every year in the contract starting at year 4. Therefore, limited funds impose a financial constraint on RTT's current EPICC model.

While Scenario F might be the best for the landowner in terms of total income, it is worth comparing Scenario B theoretical average income against Scenario F theoretical average income. Since the difference is only $44, Scenario B is the best value for RTT's dollar since it would be paying the farmer more than $1000 less for carbon payments. It is a meaningful case assuming that adequate funding is able to extend carbon payments to 25 years. Also, payments awarded each year of the contract incentivize good management of the forest and carbon stocks.

While some argue the gold standard for national climate change policy is a carbon tax, carbon dioxide commodification is an economically viable and tangible carbon *mitigation* strategy. Due to miscellaneous policy stringencies in developed countries, companies may not feel the need to offset their emissions until they are required under regulation. Meanwhile, as they begin to feel public and political pressure to reduce their emissions, more studies should examine how firms value carbon.

Pending the advent of stronger U.S. national climate change policies, carbon sequestration and commodification is a valuable option in the interim. Because there is mounting social pressure for companies and corporations to take action on climate change, RTT casts applied research and demonstration projects as a worthy cause to potential donors. However, companies that choose to act voluntarily on climate change are the leaders of corporate social responsibility. When a firm is not being regulated, and yet reduces emissions on its own, it is a virtuous act. An oil company's variable cost of carbon is high relative to others. Since oil companies are likely to become regulated in the near future, their internal prices are higher than a company like Microsoft that makes consumer goods. Therefore, firms ascribe a carbon price in anticipation of future compliance and to calculate the value of future projects. Companies with higher prices are closer to the social cost of carbon—the marginal damage from an extra ton of carbon—than to market price. With the current lack of a U.S. national policy for regulating carbon dioxide, carbon sequestration and commodification is the sleeping giant of mitigation strategies.

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