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Increasing Forest Cover for a CO_2 Neutral Future: Costa Rica Case Study[1]

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ABSTRACT

Costa Rica successfully increased forest cover from 21% to 57% between 1987 and 2017 through its PES scheme. A critical first phase culminating in recently signed agreements recognizing the reduction of 12 million tCO_{2e} emissions fixed in regenerated forestland and forest fires control with the World Bank, and 14.7 million tCO_{2e} for the results-based payment with the Green Climate Fund. The country has committed to become CO_2 neutral by 2050. Achieving this goal entails a paradigm shift in all productive sectors towards carbon neutrality; either by reducing emissions or by compensating at the national or international level. For Costa Rica, this means transforming the transportation sector, ensuring the most effective and efficient use of the forest cover that exists today, and shifting the focus from a primarily quantitative measurement of forest cover to one that further values the qualitative benefits of species utilized and services produced. In addition, halting deforestation in sensitive areas, increasing forest coverage in areas still available (approximately 3% for forest and 5% for agroforestry) incorporating agroforestry, silvopastoral and multi-use systems that will allow for more sustainable production systems increasing ecosystem services. Efforts are being undertaken to upgrade the PES scheme towards ensuring negative CO_2 emissions from the land use sector to compensate those from other economic sectors. For its success, this new generation scheme – PES 2.0 – must increase ecosystem services beyond traditional forest service, promote conversion of land under agricultural production (i.e. cattle and diary) into agroforestry operations, and increase its long term socio-economic sustainability.

Keywords: Forest; CO_2, Costa Rica, PES, Ecosystem services.

JEL classification: Q57

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Aumento de la Cobertura Forestal para un Futuro Neutral en CO_2: Estudio del Caso de Costa Rica[2]

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RESUMEN

Costa Rica aumentó, con éxito, la cobertura forestal del 21% al 57% entre 1987 y 2017 a través de su esquema de pago por servicios ambientales (PSA). Una primera fase clave culmina con los acuerdos recientemente firmados con el Banco Mundial y el Fondo Verde para el Clima, que reconocen la reducción de 12 millones de tCO2e de emisiones fijas en bosques regenerados y control de incendios forestales, y de 14,7 millones de tCO2e por pago basado en resultados. El país se ha comprometido a convertirse en CO2 neutral para el año 2050. Lograr este objetivo implica un cambio de paradigma en todos los sectores productivos hacia la neutralidad en carbono, ya sea reduciendo las emisiones o mediante compensaciones a nivel nacional o internacional. Para Costa Rica, esto significa transformar el sector del transporte, asegurar un uso más efectivo y eficiente de la cobertura forestal que el que existe en la actualidad, y cambiar el enfoque de una medición principalmente cuantitativa de la cobertura forestal a una que valore aún más los beneficios cualitativos de las especies utilizadas y servicios producidos. También significa detener la deforestación en áreas sensibles, aumentar la cobertura forestal en áreas aún disponibles (aproximadamente 3% para bosque y 5% para agroforestería) incorporando sistemas agroforestales, silvopastoriles y de usos múltiples que permitan sistemas de producción más sostenibles aumentando los servicios ecosistémáticos. Se están realizando esfuerzos para mejorar el esquema de PSA a fin de garantizar las emisiones negativas de CO2 del sector del uso de la tierra para compensar las de otros sectores económicos. Para su éxito, este esquema de nueva generación, PSA 2.0, debe incrementar los servicios ecosistémáticos más allá del servicio forestal tradicional, promover la conversión de tierras para producción agrícola (es decir, ganado y lechería) en operaciones agroforestales y aumentar su sostenibilidad socioeconómica a largo plazo.

Palabras clave: Bosque, CO_2, Costa Rica, PES, Servicios ecosistemáticos.

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1. Context

"Costa Rica is a small country with an area of about 51,000 km^2 on land, and a very diverse topography and vegetation, and was once almost 100% forested (Keogh, 1984). However, between 1950 and 1980, Costa Rica became part of the countries with the highest deforestation rate worldwide: Leonard reported a deforestation rate of 3.9% per year for the period between 1950 and 1984 and researchers claimed that the principal cause was the demand for agricultural land rather than for wood (Hartshorn et al., 1982; Leonard, 1986; Lutz et al., 1993)." (Cordero Pinchansky, 2018, p. 91).

Furthermore, during the 1980's the country carried out policies that provided positive incentives to agriculture and perverse incentives for forest conservation. For example, previous Costa Rican forestry laws considered clear-cutting forested land as an improvement, allowing those who illegally inhabited this cleared area to claim property rights over the land after a year. Figure 1 shows how in a period of 37 years forest coverage dropped from 72% to 21%[3].

Figure 1. Maps of Forestland in Costa Rica, 1950 vs. 1987

Source: Castro Salazar et al. (1998)

As a response, in the late 1980s Costa Rica eliminated reforestation subsidies that wrongly made cutting down the natural forest to plant few species, more profitable than conserving it. Other changes took place because people treated forests as an unregulated public good; open to expropriation, and squatters, rather than considering it a viable legitimate economic activity.

Another explanation for the forest recovery is that there was an economic crisis during that period that forced the government to eliminate perverse agriculture and cattle ranching subsidies. Since, as mentioned before, in Costa Rica and in the world, the main reason for people to cut forests down was to expand the agricultural frontier (FAO and UNEP, 2020), it is safe to conclude that by eliminating agricultural subsidies the country contributed to recovering its forests. In 1996, the last forest law further removed perverse incentives and established a preference to natural over planted forest. During field visits, local experts from the National System of Conservation Areas (SINAC) and Tempisque Conservation Area (ACT), shared their opinion that urbanization, together with a more diversified and service-oriented economy were relevant factors for the recovery that were not typically accounted for. Additionally, the economy is diversifying from an agricultural economy in the 1980s to one that is now exporting more than 4,355

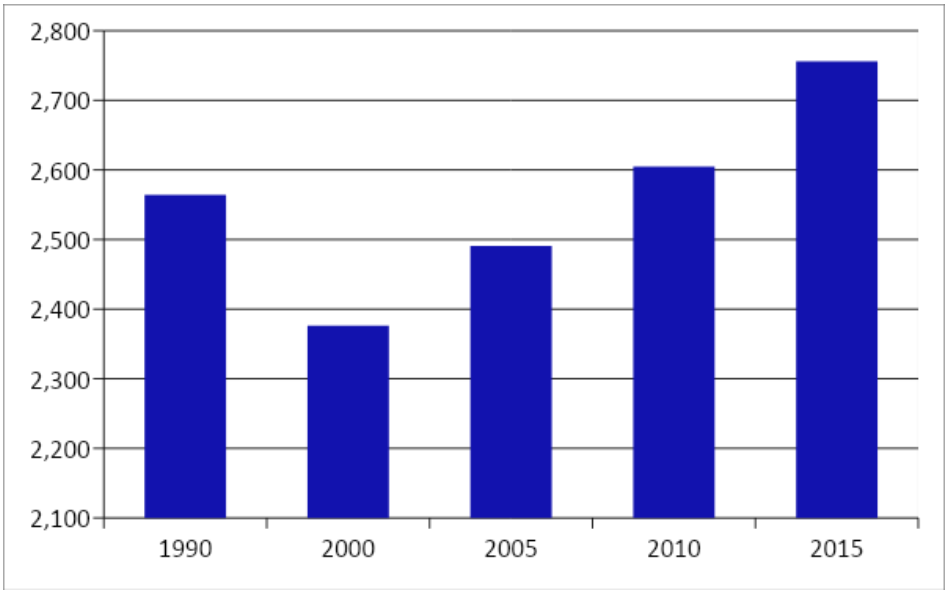
[3] It is important to consider these percentages as the best possible approximation given the technology available at the time of measurement. Specific — regional— situations could lead to variations, for instance, standing deciduous trees in the Guanacaste province (Northwest regions) could lead to under accounting.

products to 151 countries (Vicarioli, 2016). While it is hard to identify a direct correlation at this point, in all likelihood, the forest recovery benefited in different extents from the multiple changes introduced and will continue occurring in the Costa Rican economy especially after the COVID economic and social implications.

When the country introduced reforestation incentives, the situation was in fact unclear and policies were confusing and often contradictory; on one hand, landowners considered reforestation incentives a risky business; and on the other hand, people commonly deforested areas in order to make lands eligible for reforestation incentives afterward.

Figure 2 presents the turning point in deforestation, forest coverage from 1990 to 2015. In the decade 1990 - 2000 forest coverage decreased and from 2000 to 2015 there is a clear trend in recovering forest coverage as a result of the measures the country took to reverse the negative trend. Another reason for the fast recovery is that in the tropical regions, both natural forest and trees in plantations grow faster than in the other areas. For example, teak plantations reach commercial size in less than 10 years.

Figure 2. Costa Rica's Total Forest Coverage from 1990 to 2015 (1000s of ha)



Source: FAO (2015)

Costa Rica's re-greening process intensified during the early 1990s, though at the time it was impossible to determine whether the reversal in the deforestation trend was going to be sustainable or not because Costa Rica implemented a wide variety of reforestation incentives earlier, with limited success in stopping deforestation and encouraging reforestation. "Nonetheless, those early incentives partially paved the way for the creation of the PES programme" as part of the 1996 Forest Law (Porras et al., 2013, p. 8).

The current goal is to increase the forest cover up to 60% of the territory and an additional 250,000 has, equivalent to 5%, with agroforestry projects (J. M. Rodríguez, personal communication, January 19, 2021).

1.1 The beginning: State Forest and other Protected Areas

At the time, farmers were clearing forests at the rate of 50,000 hectares per year,[4] mostly to produce beef for export to the United States (Keller et al., 2013). Between 1974 and 1978 protected areas expanded from 3% to 12% of the national territory (Castro Salazar et al., 1998). It was an early reaction, under the leadership of President Daniel Oduber to keep a representative sample of the primeval nature[5] while building infrastructure and developing the country.

In 1998, for the first time, the country adopted an official policy document on the management of protected areas, promoting the sustainable use of the country's natural resources, including environmental education as a strategic component of development.

Table 1. Evolution of the Costa Rican System of National Protected Areas

National 1993				National 2011			
Management category	**Number**	**Area in 1000 ha**	**% of total territory**	**Management category**	**Number**	**Area in 1000 ha**	**% of total territory**
Category I	4	15	0.3%	National Park	28	629.3	12.3%
Category II	13	488	9.6%	Forest reserve	9	216.2	4.2%
Category III	0	0	0.0%	Biological reserve	8	21.6	0.4%
Category IV	9	129	2.5%	Protected zone	31	157.2	3.1%
Category V	3	6	0.1%	Wildlife refuge	71	237.5	4.7%
				Wetland	13	69.1	1.4%
				Special categories	4	21.8	0.4%
Total	**29**	**639**	**12.5%**		**155**	**1,353**	**26.0%**

Source: (Cordero Pinchansky, 2018, p. 118)

As observed in Table 3, from 1993 to 2011 the national protected areas more than doubled, increasing from 12.5% to 26% (MINAE et al., 2012). Since the total area covered by forest is 54%, we might therefore conclude that the area covered by forest is, as an approximation, half in private hands, and half-public—with the public land having the particularity that the government has set it aside as a protected area forever.[6]

One clarification regarding the reduction in the number of forest reserves is that many of them became national parks (see the increase in national parks), hence enhancing their level of protection. A second change is that most of the categories became de facto “non-extraction areas” with little or no difference amongst all categories. France and Costa Rica are leading a group[7] of more than 60 countries promoting the idea of expanding protected land and marine areas up to 30% of the sovereign space at the 15th Conference of the parties (COP 15) in 2021. This is an enormous challenge for Costa Rica and for the world, and it is not clear how countries will finance and monitor these areas.(*The One Planet Summit and the High Ambition Coalition for Nature and People*, 2021)

[4] This represented one of the highest deforestation rates in the world.

[5] Rene Castro Salazar personal communication with President Oduber in May 1982.

[6] The government authorized only non-extractive users like eco-tourists to enter the protected areas, and human settlement is banned.

[7] The High Ambition Coalition for Nature and People, is a group of more than 60 countries launched in Paris on January 11, 2021 amongst others by the French and Costa Rican presidents, the current co-chairs.

1.2 Changing course: Establishment of the PES framework

Since 1994, Costa Rica created the Costa Rican Office of Joint Implementation (OCIC - Spanish acronym) to prepare for Activities Implemented Jointly under the United Nations Framework Climate Change Convention and to attract international investors to its forest sector and formalized it by 1996 (MINAE, 1996).

Also in 1996, the Costa Rican government decided to restructure a dated entity created in 1991to handle a precursor generation of reforestation incentives. The entity, the National Fund for Forestry Financing (FONAFIFO), formally attached to MINAE, was assigned the responsibility–from 1996 on—of administering the funds of the PES program now established by law. Forest Law No.7575 established FONAFIFO's initial endowment, and its sources of funds. "In sum, the law established a mechanism to compensate landholders for providing environmental services, defined the sources of financing, and outlined the rules for disbursing the payments." (Cordero Pinchansky, 2018, p. 112).

In 1997, Costa Rica traded in a voluntary carbon market and sold 200,000 tons of CO_{2e} to Norway at $10 per ton for a total of $2 million paid to FONAFIFO. The country used the money for forestry financing. Commentators often cite this transaction as the first CO_2 transaction in the world, under the Kyoto Protocol. Not much funding from this source came during the next decades due to the collapse of the Kyoto Protocol mechanisms when the USA and other countries abandoned it in 2001.

Many countries have recognized Costa Rica as a pioneer in introducing the concept of environmental services, and going further, in applying the idea of environmental markets (De Camino et al., 2000; Le Coq et al., 2010; Wunder, 2007). Costa Rica led the way in 1996 to a specific policy instrument: PES included in Forest Law No.7575. Other countries experimented with payments in specific territories, yet Costa Rica designed PES to comprise the whole country; it was born as a national system (Wunder et al., 2008).

According to Cordero, "FONAFIFO's Board of Trustees is the most important decision-making body over PES in Costa Rica and it is composed of government and private sector representatives, including one from small-scale businesses", (Cordero Pinchansky, 2018, p. 96). A wide variety of systems has been introduced and tested over the years see Table 1. Notwithstanding, for the period 1997-2019 approximately 90% of the hectares under PES mechanisms were under the forest protection modality, only 6% targeted reforestation (forest plantations), 2% forest management, and 2% others. By 2015, examples in diversified models, such as agroforestry systems, capable of increasing forest cover in productive systems are few and far apart, therefore in 2020 MINAE decided to transform PES into PES 2.0 (C. M. Rodríguez, personal communication, April 6, 2020).

Furthermore, one interesting fact is that despite the payment is based on the "ecosystem services" provided, FONAFIFO does not track the flow of specific ecosystem services such as changes in water quality or carbon storage; it focuses instead on land management activities such as area reforested, and protection of areas designated as conservation forest (Bennett and Henninger, 2009). This is one of the major improvements that a PES 2.0 could provide as we will discuss in section 3.

Since 1996, the country not only had experimented with a series of incentives for reforestation and forest management, but also more importantly created the institutions to manage them. "The Forest Law built on this base, with two major changes. First, it changed the justification for payments from support for the timber industry to the provision of environmental services. Second, it changed the source of financing from the government budget to a remarkable tax on fossil fuels and payments from beneficiaries." (Pagiola, 2008). In fact, it introduced one of the first fuel tax used for forest preservation / conservation through the payment for environmental services.

Table 2. List of PES modalities by year of implementation from year 1997 to 2015

MODALITIES	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Established plantations																			
Forest management																			
Forest protection																			
Reforestation																			
Agroforestry systems																			
Reforestation in second crops																			
Protection of water resource																			
Reforestation with endangered species																			
Reforestation (multi-stage)																			
Natural regeneration (productive)																			
Natural regeneration projects (MDL)																			
Natural regeneration of pasturelands																			
Forest protection in disaster areas																			
Coffee agroforestry systems																			
Protection of wild areas																			
Protection of conservation gaps																			
Agroforestry systems with endangered species																			
Agroforestry systems with native species																			
Trees in coffee plantation																			

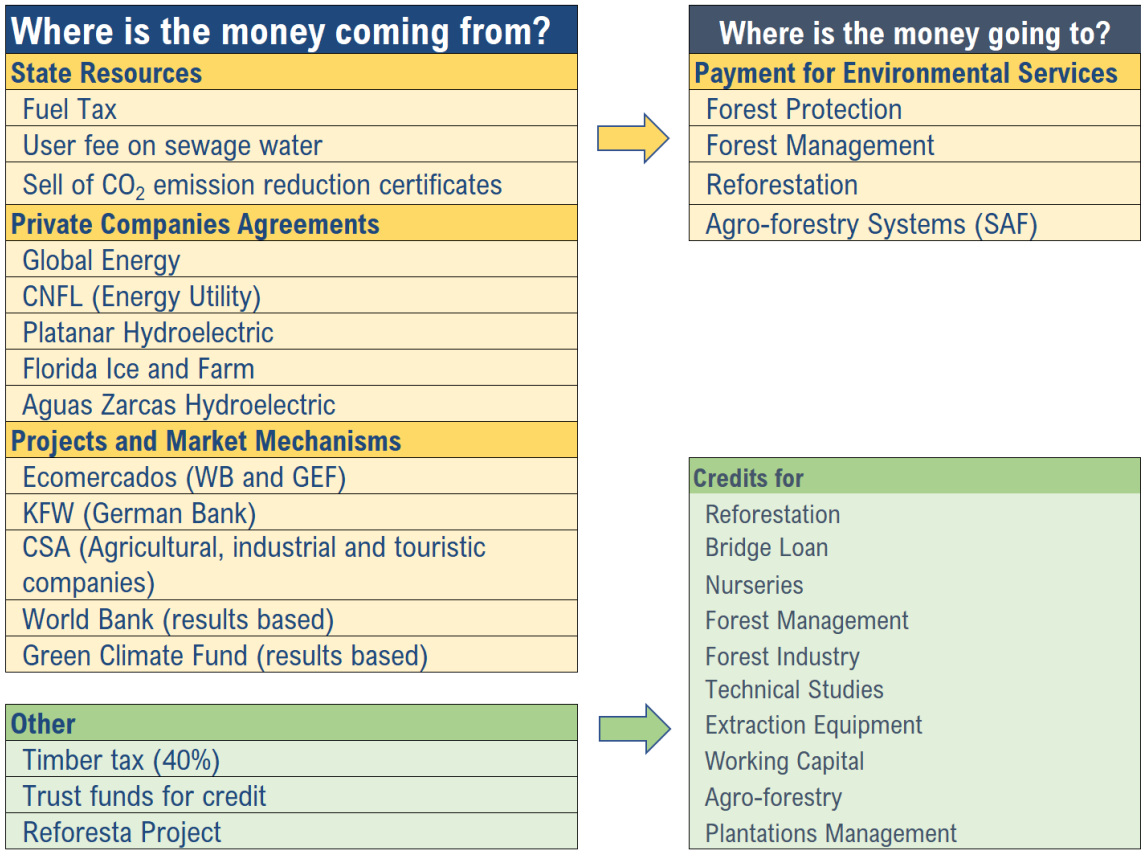
Source: FONAFIFO, 2015 cited by Allasiw et al. (2016, p. 51)

Forest Law No.7575 explicitly recognizes four of the environmental services provided by forest ecosystems, (Forestry Law, 1996);

a. Mitigation of greenhouse gas emissions;
b. Hydrological services, including provision of water for human consumption, irrigation, and energy production;
c. Biodiversity conservation; and
d. Provision of scenic beauty for recreation, tourism, and scientific uses.

The figure below presents a description of the flow of funds. The money that goes to PES comes from State resources, private agreements with companies mostly on water related services, and projects and loans. The money used on commercial loans to farmers comes from the sources shown under “other” in figure 8. A loan from the World Bank and a grant from the Global Environment Facility (GEF), through the Ecomarkets Project were the main financial sources for PES in Costa Rica from 2001 to 2006. The finance ministry should pay the loan using the inflow from the fuel tax. In other years, the finance ministry transferred the money directly to FONAFIFO. In the last quarter of 2020 MINAE, announced the signing of two major agreements, the first for US$63 million with the WB cooperative program for forest emissions reductions, and the second for US$54 million with the GCF under the results-based program. These two agreements, are the last of the first-generation of PES, which resulted in the culmination of a long process that attained a reduction of 12 million tCO_{2e} emissions fixed in regenerated forestland and forest fires control with the WB and 14.7 million tC02e for the results-based payment with the GCF.

Figure 3. Description of Funds Movements for PES in Costa Rica 1996 – 2020



Source: Adjusted by the authors from Cordero Pinchansky (2018)

The program pays landowners to conserve and sustainably manage forested areas, or to reforest degraded land. Porras *et al.* stated that since 1997, PES in Costa Rica helped to conserve nearly one million hectares of forest as a result of payments for: protection (90%), reforestation (6%), sustainable management (3%), and, lately, regeneration (1%) (Porras et al., 2013). One noteworthy fact is that PES has been part of a process seeking to address conservation in Costa Rica's private lands because the country already made a substantial effort on public lands by creating the System of Protected Areas, that are National Parks and other State-owned lands as discussed in section 2.

Costa Rica's PES experience has been a clear example of the capacity for adaptive management because FONAFIFO, based on previous results, made major social reforms (to add to the environmental objectives) based on its experience with the first generation of PES, covering for example, indigenous communities with common property rights and projects led by women as heads of the family.

Many scholars consider Costa Rica's PES as a flexible mechanism that has financial sustainability, developed in a strong regulatory system and backed by strong institutions. Moreover, PES is currently a well-established system recognized for its transparency, credibility, financing efficiency, and successful results (Daniels et al., 2010; Zbinden & Lee, 2005). Nevertheless, statistically speaking, other scholars consider that the use of PES and the recovery in forest coverage in Costa Rica statistically represent more correlation than causality.

1.2.1 The PES: Policy Process

According to Sánchez-Azofeifa et al. (2007), three laws constitute the legal framework within which Costa Rica established the PES program:

a) Environment Law No.7554 (1995) that mandates a "balanced and ecologically driven environment" for all;
b) Forestry Law No.7575 (1996) that mandates "rational use" of all natural resources and prohibits land use change in natural forest covered land; and
c) Biodiversity Law No.7788 (1998) that promotes the conservation and "rational use" of biodiversity resources.

Table 3. Summary of measures included in Law No.7575

Regulation	Economic Instruments	General Results
• veto on land use change on those lands covered by natural forest • veto on changing forestlands into forest plantations • prison penalties between 3 months and 3 years for those violating the law (i.e. illegal logging) • ban on export of wood coming from forests, in logs and squares • special permit needed to transport timber around the country • police action to remove squatters from areas under PES • Forest rangers acquired police authority regarding forest issues • Forest fires monitoring and agricultural malpractice sanctioned.	• Creation of PES, paid to landowners through the forest conservation certificate • real estate tax exemption to those receiving PES • forestland accepted as loan warranty (including the value of the forest, not just the land) • creation of FONAFIFO • establishment of the forestry fund, with the following sources: ○ 1/3 of the proceeds of the tax on fossil fuels ○ 40% of the forest tax (established in this law) ○ income from sale of wood/timber confiscated ○ user fee established on other natural resources (i.e. water) • Results based agreements signed in 2020 for CO_2 fixation with WB and GCF at $5 per ton CO_{2e}.	● From 1997 to 2010, 770,000 hectares were included in the program. 85% under forest protection and 15% distributed in reforestation and other modalities. ● 8500 families involved in the program. ● Generate employment (day labor, forestry engineer, notary service, surveyors, etc.). ● An investment that exceeds $200,000,000 in rural areas. ● In that period net forest cover increased by 7.5% ● 26.7 million tons of CO_2 fixed. ● A substantial reduction in forest fires and creation of more than 1,000 forest fighters volunteers trained and equipped.

Source: Based on Cordero Pinchansky (2018, p. 109) and adapted by authors.

The most relevant to this paper, Forestry Law No.7575 was promulgated in February 1996 with strong political support from the Government of President José María Figueres. The law, among other actions, legally established PES. The law adapted the existing system of financial incentives for reforestation and provided the legal basis to compensate landholders for providing ecosystem services. A new Certificate for Forest Conservation (COB – Spanish acronym) rewarded landholders for their ecosystem services. FONAFIFO was set up to manage the program in collaboration with other governmental and non-governmental organizations. The law expanded the sources of financing for the program to various resources at FONAFIFO's disposal: tax (dedicated fuel tax) revenues, grants and loans from national and international institutions, debt relief, agreements with the private sector, and market instruments (Bennett and Henninger, 2009; Chomitz et al., 1998).

In addition, Forestry Law No.7575 banned all land use change of established natural forests, punishable by prison sentences rather than only fines as was previously used. The fact that the offer to pay land-owners for reforesting, protecting forest, or managing existing forest in private properties outside national parks, helped to enhance conservation on private lands that were not under extractive forest regimes (Porras et al., 2013).

As observed in Table 3, the Forestry Law enacted in 1996 is a fusion of regulation and market-based instruments (MBIs), which policy makers combined to improve results. Policy makers presented a law that even included the sources of funding, in order to ensure the success and sustainability of the economic instruments.

1.3 The new challenge: a climate change goal by 2050

In 2009 Costa Rica designed a National Climate Change Strategy, after signing the Paris agreement for climate in 2015, Costa Rica is now part of the of the growing number of countries committing to become CO_2 neutral by 2050[8]. Historically, the country has had important achievements in combating climate change; for example, the country adopted in 1997 a fuel tax to finance PES, which has helped in becoming one of the few tropical countries to have reversed deforestation and have an electricity matrix with more than 90% renewable energy.

We mentioned that in the last quarter of 2020 the Costa Rican ministry for the environment and energy MINAE, announced the signing of an agreement with the WB and the GCF, these two agreements are likely to be the last ones of the first-generation PES (J. M. Rodríguez, personal communication, December 11, 2020) as they were the culmination of a long process that represented 14.7 million and 12 million of CO_2 emissions fixed in regenerated forestland. Now the forest sector and the country need to find more agile instruments to achieve its CO_2 neutral goals by 2050.

Costa Rica officially launched its Decarbonization Plan in February 2019, which expressed the country's commitment to "*becoming a decarbonized economy with net-zero emissions by 2050*" (Government of Costa Rica, 2019a). The plan guided the development of the National Development and Public Investment Plan (2018-2022) and the new Costa Rica 2050 Strategic Plan. Furthermore, it encourages green growth and highlights ten focus areas to reverse the increase of greenhouse gas emissions (GHG), spanning from mobility to agriculture (Government of Costa Rica, 2017).

According to the national inventory conducted in 2015, Costa Rica's per capita CO_{2e} emissions amounted to 2.25 tons. As shown in Table 4, from the total emissions produced in 2015, the energy sector and predominantly the transportation subsector—which is included within the energy one—was the most polluting sector, with 7.3 $MtCO_{2e}$ emissions released. Moreover, the transportation subsector is the

[8] Between November 2020 and February 2021, more than 120 countries area adopting neutrality goals, countries like Japan, Korea and more recently the USA has pledged to become CO_2 neutral by 2050 and China by 2060.

country's "Achilles' heel", accounting for roughly 51% of total emissions as of 2015, (Government of Costa Rica, 2019b).

Table 4. Costa Rica, greenhouse gasses emissions as CO_{2e} from 2005 to 2015

Source of Emissions	Emissions expressed as CO_2 equivalent (Mt)		
	2005	2010	2015
Energy	5.92	7.03	7.30
Industrial processes	0.63	0.83	1.32
AFOLU (agriculture, forest, and land use)	0.25	2.20	0.18
Waste	1.32	1.38	2.08
Total	**8.12**	**11.44**	**10.88**

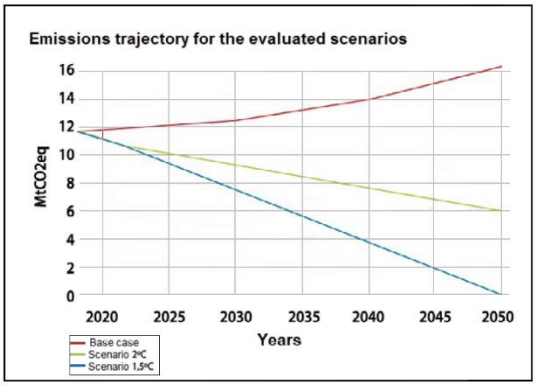
Source: (Government of Costa Rica, 2019b)

Conversely, more than 98% of Costa Rica's electricity derives from traditional renewable sources with a low carbon footprint[9] (Government of Costa Rica, 2019a). The energy sector is then followed by the waste sector in terms of emissions produced (2.08 $MtCO_{2e}$ in 2015), the industrial processes sector (1.32 $MtCO_{2e}$), and the AFOLU sector (0.18 $MtCO_{2e}$).

The data available, shows that emissions increased from 2005 to 2010 and decreased from 2010 to 2015. In addition, estimations indicate that total emissions are expected to decrease 15% between 2010 and 2030, going from 11.44 $MTCO_{2e}$ to 9.7 $MTCO_{2e}$ (Government of Costa Rica, 2019b). Moreover, the AFOLU sector is expected to decrease its emissions by 96%, followed by industrial processes (-13%), and energy (-1%). The only sector that is expected to maintain a net positive impact in terms of emissions' production is waste, experiencing an increase of 29%.

The forestry sector will have to play a prominent role in the short and medium terms, for Costa Rica to achieve net-zero emissions. Thus, carbon sequestration achieved by forest land should be a crucial tool in a path towards carbon neutrality. As an example, Figure 4 shows that for the 2° Celsius scenario in 2050, forests in Costa Rica were estimated as responsible for the sequestration of 3.5 $MtCO_{2e}$ and for the 1.5° Celsius scenario, forest sequestration would increase up to 5.5 $MtCO_{2e}$.

Figure 4. Costa Rica emissions trajectory 2020 to 2050 and estimates for the evaluated scenarios (2050)



Emissions estimates for the generated scenarios ($MtCO_{2e}$)

Sector	Reference GHG 2012 Inventory (IMN)	Base case scenario (2050)	Scenario 2°C (2050)	Scenario 1.5°C (2050)
Energy	7.21	9.48	4.54	2.64
Industrial processes	0.98	1.41	0.68	0.39
Agriculture	3.24	5.90	2.82	1.64
Waste	1.86	2.97	1.42	0.83
Net forest area	-2.05	-3.50	-3.50	-5.50
Total	**11.24**	**16.26**	**5.96**	**0.00**

Source: (Government of Costa Rica, 2019a, p. 25)

[9] Such as hydropower, wind, solar, biomass, and geothermal energy. Costa Rica has never included nuclear power in its power development plans.

In the long-term, the fundamental solution will be to enhance energy efficiency, reduce CO_2 emissions per unit produced (i.e., CO_2 per kWh in the energy sector), and decrease the use of fossil fuels per kilometer (i.e., CO_2 per km). In other words, Costa Rica could decrease emissions in all sectors by increasing drastically energy efficiency, using the forestry sector for any deficit in other sectors like transportation, as well as promoting the modernization and dynamization of the economy under a green growth vision (Government of Costa Rica, 2018).

1.4 Can forest compensate the CO_2 gap? It depends on land productivity dynamics

This paper indicates, that the main change in Costa Rican land use since 1950 has been the transformation of forests into pastures and farmland. We observed as well, that in the early years the country linked the predominant vision of development and economic growth to agro-export production, supporting the expansion of agriculture and cattle ranching and then it changed its course. Is this new course sustainable? Can forest cover grow a bit more and be part of the country's development engines?

As researchers pointed out, we need to distinguish between land capability and actual land use. In 1984, land capability studies in Costa Rica found that 44% of the land was suited for agricultural use and 56% for forest use; while in reality, 58% was under agriculture use and only 34% was covered by forest. Clearly, the land use composition was a consequence of market forces and policy distortions, which moved land use away from the pattern suggested, based on sustainable use of land resources (Peuker, 1992).

In sum, the evolution of land use in Costa Rica depended not only on the policies, but also on the change in the public's attitude towards forests. Different laws formalized these attitudes, according to the relative power of the various interest groups.

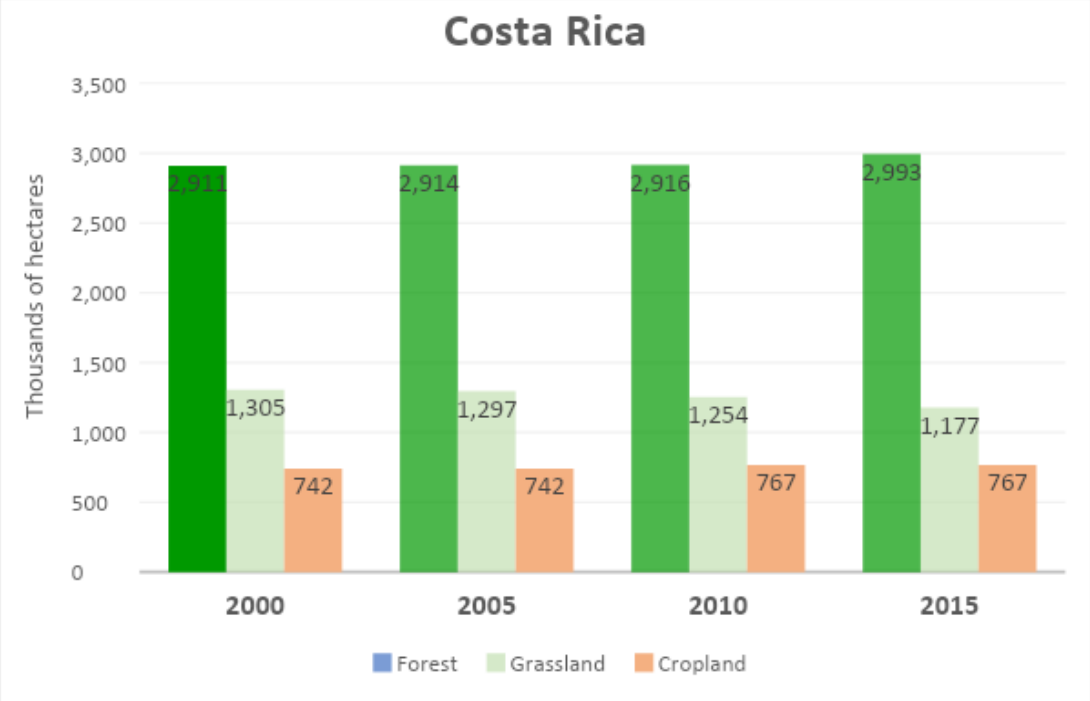
Figure 5 below, shows that the prevalent land use in the country is forest, which represents more than 50% of the territory. The trend in land use for forests is positive (growing since 2000). Despite being an exporter of pineapple, coffee, and banana, the area used for crops is just about 15% of the country with a slight increase in 2010 due to the increase in pineapple exports. In addition, grassland has been decreasing and the land for settlements remain constant at about 2% of the country, which indicates a constant trend for urbanization. It also shows the country's priorities, were forest coverage for protection of ecosystem services is among the main ones.

As of 2018, Costa Rica's land use[10] was estimated to be primarily classified as 71% forest—including shrubs and herbaceous cover— (light and dark green areas, and light brown in Figure 6A), 27% cropland including rainfed (yellow and orange areas in Figure 6A), 1% settlements (red area) and 1% water bodies. Other areas such as grassland and wetlands were considered statistically negligible. This consideration is particularly relevant when determining the areas of focus to target the new PES 2.0, and the socio-cultural conditions of the populations where these mechanisms should be set in place, to increase forest cover and CO_2 sequestration through productive systems.

Furthermore, as seen in Figure 6B below 15.6% of the national territory is suffering declining productivity, a further 10.2% presents early signs of decline. On the other hand, 51.1% is stable and not stressed and a further 19.4% is increasing productivity. The north pacific area of Costa Rica holds in one hand, a large quantity of stable soils with increasing productivity which present a high concentration of agricultural land, and on the other hand, this area is the semi-arid portion of Costa Rica and has high risk of land degradation and erosion. Special attention must also be placed to the north Caribbean coast which presents high levels of declining productivity, and the south pacific coast which presents early signs of declining productivity.

[10] As defined by the Intergovernmental Panel on Climate Change (IPCC).

Figure 5. Costa Rica, Evolution in Land Use 2000 - 2015[11]

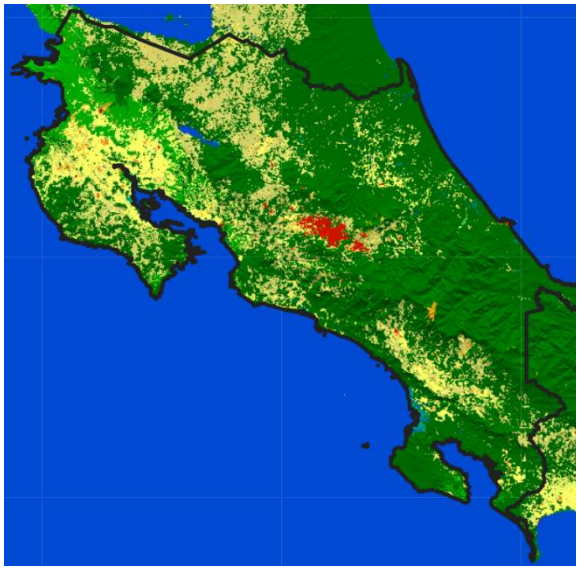


Source: Danilo Molliconi, FAO´s team leader, developing and working with Collect Earth for real time assessing of the forest and land use changes all over the world, cited by (Cordero Pinchansky, 2018)

Additionally, as presented in "The global tree restoration potential" and shown in Figure 7 below, it is relevant to consider the extrapolation of the risk of loss and areas with the restoration potential, which coincide in the center north of the country (Bastin et al., 2019). An additional area with potential for restoration is the great metropolitan area, fact that could pose a major challenge considering the increased levels of urbanization. In addition, there is restoration potential in the territories between the Braulio Carrillo National Park and the Tortuguero National Park in the north Caribbean, where high levels of declining productivity are already present and in the south pacific territory leading to Corcovado National park which presents early signs of declining productivity. These last two territories have agglomerations of population and could significantly benefit from land restoration using economic incentives to further promote the growing eco-tourism capacities of the region.

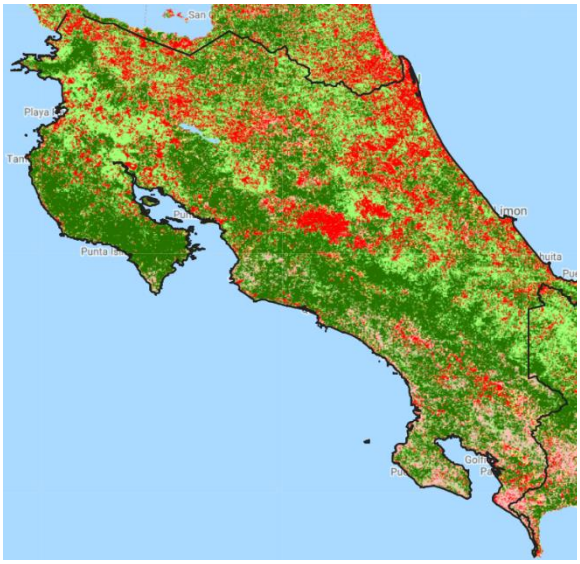
[11] Mr. Mollicone's team produced the first report for forest in dry lands (published in Science in 2016), covering 45% of the land mass. The users and stakeholders include Google Earth and more than 30 countries like US, Germany, Australia, Papa New Guinea, Paraguay, Costa Rica and Mexico.

Figure 6. A) Land Cover and B) Land productivity Dynamics



A)

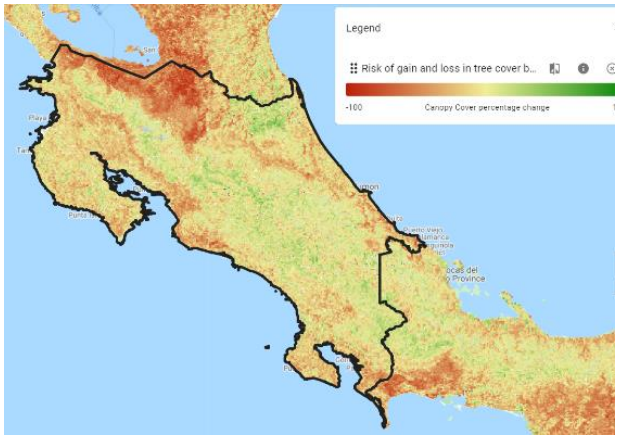
Source: (hiip://www.esa-landcover-cci.org/)



B)

Source: FAO Geospatial Platform. Earth Map, Google Earth Engine.

Figure 7. A) Risk of gain and loss in tree cover by 2050 and B) Restoration Potential



A)

B)

Source: (Bastin et al., 2019) presented in FAO Geospatial Platform. Earth Map, Google Earth Engine.

2. The CO2 neutrality Goal: Challenges to Implementation

Notwithstanding the enormous success and international recognition that the program has, many challenges remain. The PES program has created solid bases and all along the implementation of the first-phase, lessons, gaps, and areas of improvement were identified. In this section, we will present some of the most relevant ones identified in the first generation of PES and in the first experiences with agroforestry systems, which may constitute a fundamental part of the PES 2.0.

There are three main areas where we consider important challenges remain, though, if treated, would ensure a robust forward-looking framework that could be easily scalable within the region and abroad. The three main areas that might be strengthened are: technical knowledge and capacities, enhancing social inclusion and social benefits, and ensuring a consistent and overarching political understanding.

While the challenges are, to some extent, "static" and can be identified in many similar programs, the solutions are "dynamic" and as such, must allow for the sufficient flexibility to adapt to changing times.

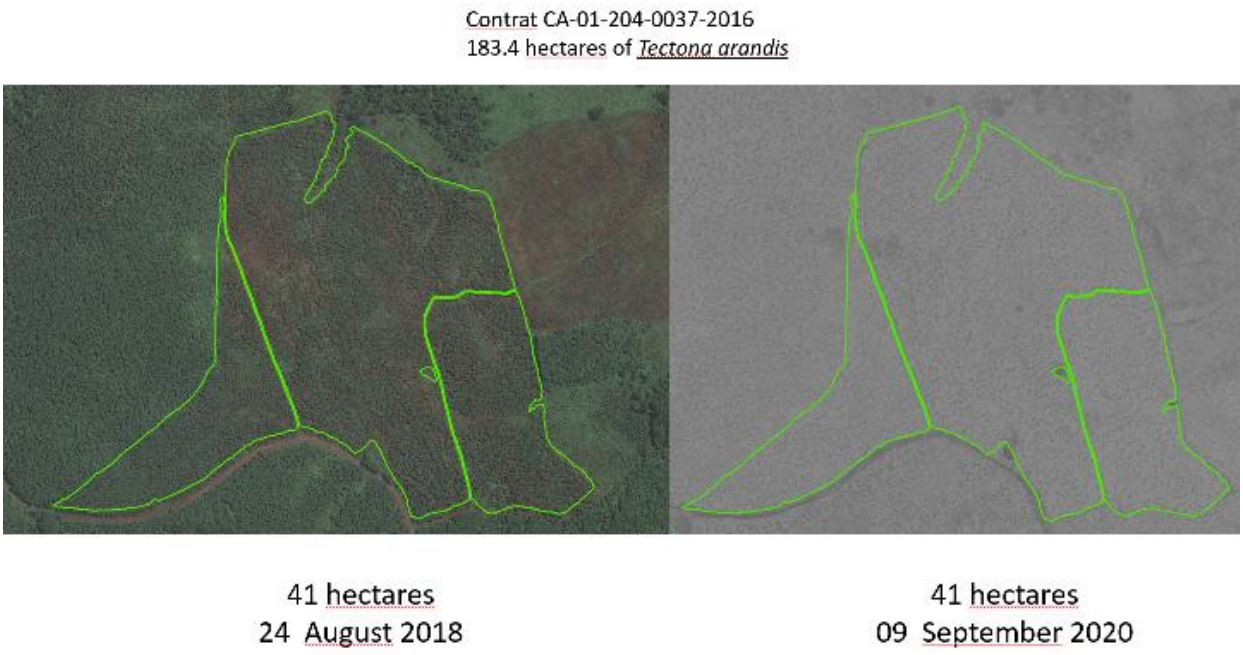
Technical challenges

The first challenge identified is to ensure adequate implementation support for quality monitoring and evaluation. Plots are commonly based in remote areas with limited access, and the use of geospatial tools for monitoring is only beginning. FONAFIFO relies on its own staff and forest engineers to design forestry plans and provide on-site supervision. Field visits are limited as the human resources available are insufficient to provide sufficient guidance and supervision. Additionally, the risk of an expert playing both, judge and jury on a specific plot, require conducting independent evaluations to reassure the quality of the evaluations and flag potential issues to be addressed.

CATIE agroforestry experts noted that some farmers have little interest in maintaining a good quality agroforestry farm, and are only motivated to increase the number of trees planted so that they receive larger payments. Also, they pointed out that only planting more trees does not necessarily translate to an increase in biodiversity.

Recently FONAFIFO started using remote sensing to monitor periodically all contracts, see Figure 8. Although important advances have been made in delineate plots, cloud cover remains an issue, limiting the quality and use of images in certain areas of the country.

Figure 8. FONAFIFO's use of enhanced remote sensing to monitor contracts.



Source: The example is contract CA-01-204-2016 of Tectona Grandis with images from August 2018 and September 2020, provided by SecureWatch, a commercial company providing real time images within 48 hours and a library of at least 5 years.

In general, Costa Rica presents some examples of best practices of sustainable land management and agroforestry systems, though they do not easily nor often reach the hands of the land owners and farmers currently trying to implement those systems. We believe FONAFIFO could easily make them available and could also improve technology transfer and monitoring abilities.

Before 2018, the individual contracts' monitoring needed the physical presence of forest engineers. Afterwards, the use of enhanced remote sensing enabled the PES program to increase its reach to areas

that were previously difficult to reach. The launching of a Costa Rican small satellite in April 2018, allowed the country to monitor CO_2 fixation in the forest in real time.[12]

Social Challenges

The PES program was not designed or intended as a poverty alleviation or social inclusion mechanism, in this sense the sole focus on increasing forest cover was pragmatic but limited its potential. Throughout the years, selection criteria shifted from a first come - first serve basis, to one which prioritized ecosystem benefits in the four key environmental services and regions of the country. This led to a concentration of PES systems in rich forest areas such as the Península de Osa in the South Pacific, and de facto limited participation of PES systems in more vulnerable areas facing increasing degradation from an expanding agricultural frontier such as the North Pacific semi-arid region. In general, FONAFIFO has been successful to show its ability to include a growing number of small landholders. However, policies to avoid elite capture and promote access by vulnerable populations, such as women and indigenous groups, were not present in the inception of the program and have lagged behind. In 2013, special mechanisms were introduced to allow participation of community owned indigenous lands.

A World Bank evaluation on the participation of women in the nation's PES schemes stated:

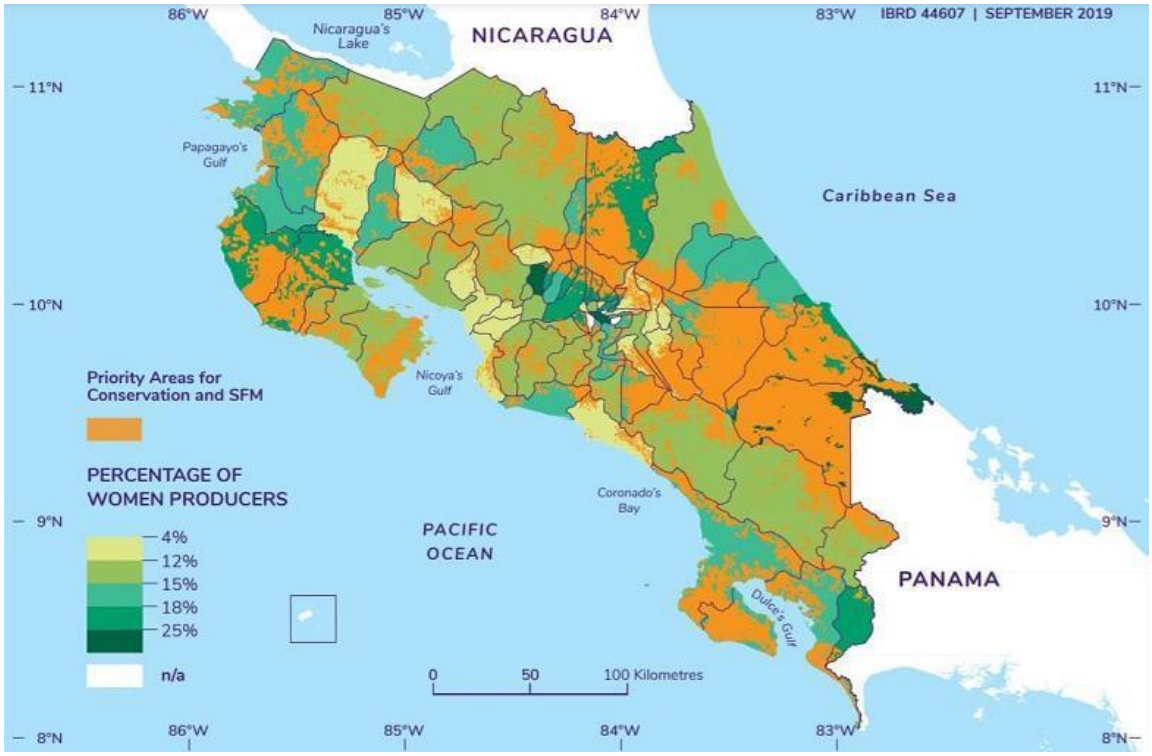
> *"Costa Rican women are important conservation agents, who are actively involved in the sustainable management of forest resources and agricultural systems, but their roles are often marginalized. Women own less land and fewer and smaller farms than men, receive less financial support for them, and participate less in Costa Rica's payment for environmental services (PES) program. Women have less access to information and services and face greater difficulty participating in forest activities and projects due to caregiving responsibilities and gender stereotypes." (World Bank, 2020).*

By 2020, following the approval of the Gender Action Plan, the program introduced a gender criterion in the evaluation matrix for selection of its annual contracts as an affirmative action. This led to approximately 10% of total area covered in the annual contracts for the period, to be owned by women. This is an important advancement yet will not be the solution to land ownership gender gaps "Roughly 12,600 women producers own 106,500 hectares of land in different regions of the country, accounting for about 15% of all farms and 8% of the total agricultural land owned by individuals in Costa Rica." (World Bank, 2020).

It will be especially important for the PES system to include these gender issues when defining the PES 2.0, considering, not only land territories facing degradation and declining productivity, but also the populations in those territories that would be most benefited by sustainable land management. Figure 9 below, presents the overlap of priority conservation areas with those presenting a higher percentage of women producers. In relation to degraded territories, there are important overlaps in the north and south Pacific coasts and in Sarapiquí, Heredia province in the north Caribbean.

[12] Costa Rica launched a Nano satellite April 2 2018, called Irazú. It first headed for the International Space Station on a Falcon 9 rocket and the used a Japanese vehicle to start orbiting the earth. The main monitoring activities are CO_2 in forest as well as humidity and temperature. One of the authors was involved in this project.

Figure 9. Percentage of women producers and priority areas for conservation and sustainable forest management.



Source: (World Bank, 2020)

FONAFIFO board of director examined 1,636 contracts signed between January 2015 and July 2017. The study shows that 67% of the contracts analyzed were with landlords that owned 50 hectares or less and cumulatively 86% of the contracts were with landlords with less than 100 hectares. This suggest that, for the period studied, the majority of beneficiaries are smaller actors, and there is an important space for women's participation. In addition, interviews to FONAFIFO senior management confirmed that very few of these contracts included landlords who own less than 5 to 10 ha., due to the high transaction costs. This might be a result of the priority on forest coverage and thus hints that there is an untapped social impact potential with smallholders. Finally, all contracts greater than 300 ha. are with indigenous associations or communal tribal property (J. M. Rodríguez, personal communication, January 19, 2021).

Table 5. Number of PES contracts per farm scale, 2015-2017

Scale/Year	2015	2016	2017*	Total 2015-2017	% per farm scale	Cumulative %
Less than 50 has	471	434	186	1091	67%	67%
Between 50-100 has	107	122	84	313	19%	86%
Between 100-300 has	91	84	26	201	12%	98%
Greater than 300 has	14	9	8	31	2%	100%
Total per year	**683**	**649**	**304**	**1636**	**100%**	

Source: (J. M. Rodríguez, 2017). Percentage calculations by the authors.
*Note: Year 2017 data is incomplete, only included contracts signed by July 2017.

The contract signed with the GCF in 2020, established that at least 200 land restoration projects will be implemented by households led by rural women. This has proven to be particularly relevant in indigenous communities and has empowered women, and as a result, a growing number of other entrepreneurial activities like cacao production emerged.

Political Challenges

While the PES mechanism has benefited from a substantive and consistent support throughout the years of various governmental administrations from different political parties, it is not exempt from political discord. This is also the case in Costa Rica, where the entry point of the ministries of Environment and Agriculture do not always meet eye to eye. As discussed with experts from SINAC, the conflicting instructions, priorities, and goals generate confusion amongst farmers and local communities. A holistic approach considering agricultural requirements for food security and practices with environmental benefits considering long term climate change adaptation, are essential for the successful implementation of a PES program exceling in agroforestry systems.

The adherence to the Paris agreement and the country's pledge to become CO_2 neutral by 2050, will introduce significant changes in the development course and money sources. First, Costa Rica through Decree No.36693 dictated a temporary moratorium to extract oil (Oil Extraction Moratorium, 2011), then in June 2013, the country cancelled a large project with China to revamp the old oil refinery and these two "temporary" decisions will now become permanent as the country migrates from fossil fuels to cleaner fuels such as hydrogen and electricity for transportation.

Second, the main source of funding for FONAFIFO and the forest recovery since 1996, is a carbon tax on fuel. This source will dry as the fuel switch is implemented and almost certainly by 2050 will be minuscule or even zero, creating the need for a new financing source for the PES 2.0. It is very likely that it will come from local activities like ecotourism and water production, combined with some international recognition to *in situ* biodiversity conservation payment, similar to those discussed in the Dasgupta review "The economics of biodiversity" (Dasgupta, 2021).

3. Opportunities for improvement

One of the most direct ways of advancement is to enhance the technical knowledge of farmers on agroforestry and genetic improvement (better plant seeds, animal breeds more resilient to heat and droughts). In order to improve implementation, we need to educate and provide technical assistance to farmers, persuading them of the benefits to follow good agriculture/environmental/social practices for a fully functioning agroforestry farm. In the past that was offered by experts from the Ministry of Agriculture and Livestock (MAG), ministry responsible of agriculture and cattle but now a days it depends more from private providers and farmer to farmer knowledge transmission.

PES 2.0 could benefit from the implementation of blockchain technology, improving capacities for traceability and monitoring. This sophistication of the system would also allow Costa Rica to participate in high demand international markets and receive a premium price for transparency and quality. While this mechanism is in no way a silver bullet for improved implementation of land management, good capacity building, together with market pressure for effective implementation, which has a direct impact on the pricing received, can motivate PES sellers to implement higher quality systems producing more and better ecosystem services. In parallel, the mechanism will support monitoring efforts linking the registered contract to global open-access remote sensing algorithms for verification.

On the other hand, to address the perverse incentive arising from the payment being made based on the number of trees planted, the new performance-based payment scheme signed with the WB and GCF help to improve forest quality. This can and should incorporate the possibility of expanding the PES mechanism towards one valuing and investing in social impact; the implementation of nature-based solutions with a social focus can be a driver for long term sustainability and generate win-win scenarios for all. FONAFIFO could play a catalyzing role in aligning social and environmental programs, by providing additional resources to finance the capacity building and establishment of new PES systems with high potential social impact, integrating vulnerable social groups who would otherwise see their participation

limited. For this, we must review local governance to ensure climate considerations influence social policies and vice versa, and ensure a multi-sectoral coordination.

In this sense, and considering the multiple limitations addressed above, the authors consider the greatest opportunity for improvement to be in a PES2.0 for agroforestry. Although it will continue to be a state-driven program, different groups can take the lead in developing PES through different activities; for example, CATIE and the forest associations could play a more active role during the design and implementation of the PES 2.0.

This system allows for the program to cope with a changing political climate as well as fund availability. The presidential term in Costa Rica lasts only four years and a president can only be reelected in non-consecutive elections. Based on this premise, PES proponents in 1997 designed it to be flexible as a safeguard to ensure the continuity of PES despite predictable changes in government priorities as each new president was sworn into office.

In this sense, the executive decree issued annually by MINAE identifies priority criteria for each modality of PES, including how many hectares are eligible for funding and how much is to be paid for each modality, making the program flexible to changing needs. This flexibility allows for the program to implement changes within a short period of time, ensuring an efficient use of funds. For example, during the initial implementation of PES for agroforestry the amount of payment for each tree was constant and did differentiate between native and foreign tree species. However, in 2014 FONAFIFO started to implement a higher payment for native species in danger of extinction. Starting in 2020, the PES will be more results oriented in terms of CO_2 fixation accordingly with the contracts signed with both the WB and GCF.

To be fully part of the Costa Rican pledge for CO_2 neutrality goal by 2050, it will be necessary to include FONAFIFO in the decarbonization law or modify the Forest law No.7575 in order to facilitate coordination and negotiation with other economic sectors such as energy and transportation and to link its domestic activities with the international arena in a more active and efficient way. Also, it is likely that an international market for CO_2 offsets will grow with the Paris agreement and FONAFIFO could become an early player with few competitors in the developing world, it could become a partner of CO_2 banks[13] similar to the one announced by the Rabobank last February 2021 (“Rabobank Is Tapping into a New Revenue Model: Carbon Banking,” 2021).

4. Summary

After changing undesirable policies and perverse incentives, Costa Rica reversed the high deforestation rates of the 1970s, and by the year 2017, recovered its forest coverage reaching 57% of the territory (Cordero Pinchansky, 2018), and is now aiming to increase forest covert to an additional 3% -5% with land restoration projects and agroforestry. Furthermore, Costa Rica has been in the forefront internationally in its efforts to stop and reverse deforestation, and preserve wild lands and biodiversity. The Costa Rican experience has significance that goes beyond its small size. The country has special attributes, such as democratic stability, an educated and environmentally aware citizenry, and a more egalitarian culture than most developing countries (Cecchini et al., 2015; ECLAC, 2010).

“The forest policy applied in Costa Rica, through Law No.7575 is in fact a policy mix, a hybrid policy that includes command and control and MBIs, that takes into account forest, land use, and climate change. In an indirect way the law also helps defining property rights, because when a farmer applies for PES, it is a requisite to present the land title. In many rural regions of the country a movement towards legalizing all

[13] In 2013 FONAFIFO and MINAE announced their project to launch and inter-sectorial and international Costa Rican CO_2 bank. In May 2014, a new government decided not to continue the project.

land titles progressed and created a clearer territorial ordering. It is also a mix of international policies with strong national ideas, which are the result of many different groups studying, testing through pilot projects, and participating in a national dialogue. Although we cannot conclude that the fact that Costa Rica reversed deforestation is a direct result of Forestry Law No.7575, most of the primary and secondary sources studied coincide on the importance the changes included in the law had on this positive result. In addition, they coincide on the importance that well-defined property rights had on the results of Costa Rica's PES program." (Cordero Pinchansky, 2018, p. 125)

Given the results obtained by the first generation of PES, the authors recommend to modify Law No.7575 in order to transform the existing PES into PES 2.0 to make them more inclusive for small farmers, more inclusive for women, focus in the ecosystem under multiple uses instead of trees only, create rural jobs and attract a larger share of international resources. Forests are crucial to achieve CO_2 neutrality by 2050, the economic incentives need to be revolutionized, towards a more agile and fast process (from project elaboration to actual implementation in the field) that includes intersectoral collaboration, if Costa Rica wants to use forest to compensate CO_2 emissions from sectors like transportation.

To achieve the goal of CO_2 neutrality at least 60% of the territory will have forest cover and another 5% will be with agroforestry projects including soil improvement. This PES 2.0 will fixed (all together) around 3.5 $MtCO_{2e}$ in the year 2050 and will continue to be relevant to compensate the CO_2 emissions year by year.

What should be included/changed to make it more agile?

FONAFIFO board includes both public and private sector representatives and that composition is useful for activities such as an annual negotiation of budget allocation and raise alarm about excess bureaucracy in the contractual process between the entity and the farmers. On the contrary, old practices like mortgaging the property in order to receive PES is expensive and limits farmers with multiple productive activities to join (i.e., a cattle grower is unlikely to mortgage its land for an agroforestry project) Therefore, a more modern system of collateral guaranties will be important, for example, a cattle grower can offer the cow as collateral to the banks, the same principle could be used for standing trees rather than the preferred mortgage of the land.

What changes might accelerate the process?

Most of the changes for a PES 2.0 could be part of the changing rules for the new annual programs to be approved by FONAFIFO´s board; in addition, it may require some consensus building effort with the *Contraloría General de la República* (Country's general comptroller), MINAE, and with the experts monitoring the projects.

However, to be fully part of the Costa Rican pledge for CO_2 neutrality goal by 2050, it will be necessary to include FONAFIFO's programs in the decarbonization law, in order to facilitate coordination and negotiation with other economic sectors, such as energy and transportation. It is also likely, that an international market for CO_2 offsets will grow with the implementation of the Paris agreement and FONAFIFO could become an early player with few competitors in the developing world.

Finally, FONAFIFO needs a transformative overhaul to become a more active entity in the international arena, to allow a more proactive role of the private sector, and to help the country achieve its CO_2 neutral role over the next 30 years. For example, it could become a partner of CO_2 banks similar to the one announced by the Rabobank last February 2021. For a more active international role, Law No.7575 will need to be modernized to face the new green businesses' trend.

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List of Acronyms

ACT	Tempisque Conservation Area, Spanish acronym (Costa Rica)
CO_2	Carbon dioxide
COB	Certificate for Forest Conservation, Spanish acronym (Costa Rica)
COP 15	United Nations Climate Change 15 Conference of the Parties, held in Copenhagen in 2009
FAO	Food and Agriculture Organization of the United Nations
FONAFIFO	National Fund for Forestry Financing, Spanish acronym (Costa Rica)
GCF	Green Climate Fund
GEF	Global Environment Facility
IMN	National Meteorological Institute
IPCC	Intergovernmental Panel on Climate Change
MAG	Ministry of Agriculture and Livestock, Spanish acronym (Costa Rica)
MBIs	Market-based instruments
MINAE	Ministry of Environment and Energy, Spanish acronym (Costa Rica)
$MtCO_{2e}$	Million tons of CO_2 equivalent
OCIC	Costa Rican Office of Joint Implementation
PES	Payment for Environmental/Ecosystem Services
REDD	Emissions Reduction from Deforestation and Forest Degradation
REDD+	Emissions Reduction from Deforestation, Forest Degradation, and Avoided Deforestation
SINAC	National System of Conservation Areas, Spanish acronym (Costa Rica)
UNED	National University at a Distance, Spanish acronym (Costa Rica)
WB	World Bank