Lessons from the past, perspectives for the future: Reforestation and the 2015 NDCs of Costa Rica and Brazil

Combining Biological, Policy and Socio-Economic perspectives

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24-02-2023
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"Many individuals are doing what they can.
But real success can only come if there is a change in our societies, our economics, and in our politics."

- Sir David Attenborough

ABSTRACT

Climate change is becoming an increasingly pressing global problem. To reach the 1.5℃ goal set by the United Nations, the Paris Agreement relies on countries' NDCs submitted every five years. This paper analysed Costa Rica's and Brazil's reforestation actions as part of their 2015 NDCs. It described how reforestation was incorporated into their NDC and analysed their actions and corresponding outcomes in the following five years. Analysis of the current progress tracking methods for NDCs showed a lack of a common structure and set of rules for reporting mitigation targets. Given the absence of such structure and rules, combined with the accompanying need for a multidisciplinary and contextual overview, this paper adopted the 2020 Global Forest Resource Assessment Framework for analyses. Moreover, in adopting this framework, the progress of both countries was analysed from three different disciplinary perspectives: biology, policy, and socio-economics. In both case studies, a historical outline of both countries' developments in reforestation was described and showed how their policy incentives adopt a dissimilar strategy in motivating reforestation efforts. Subsequent descriptions of the NDCs showed how both countries incorporated significant reforestation goals into their mitigation plans. The analyses of both countries' actions regarding their set goals using the frameworks showed how Costa Rica was likely to exceed its goals while Brazil's forests were declining and emissions were rising as a result of the changes in their political landscape. While Brazil showed increasing rates of deforestation, adequate financial incentives that motivate landholders on a national scale to increase reforestation could be an effective strategy to reverse this trend, as the results of the Costa Rica case and other studies suggest. A comparison and integration of the cases and their placement in the context of global trends in literature enabled the identification of more widespread pitfalls and enabling conditions, suggesting the potential of national scale adequate PES-systems in Brazil and the need for improved goal setting and monitoring practices. The outcomes of the research provide lessons for current and future reforestation projects and sets one step closer to more effective goal setting and successful reforestation to mitigate the effects of climate change.

KEY WORDS: ***reforestation, NDC, Costa Rica, Brazil, climate change, NBNE, NET.***

LAYMAN'S SUMMARY

Global temperatures are rising. As a result, our natural systems have already suffered numerous negative consequences in their functioning and survival. If global temperatures continue to rise at this speed, this could lead to significant dangers worldwide, such as hunger, drought, and conflict. To mitigate these negative impacts, the United Nations has formed the Paris Agreement, in which countries commit to a maximum temperature increase of 1.5℃ by 2100. To achieve these goals, every five years, countries worldwide hand in their Nationally Determined Contribution (NDC), a report that outlines their intended actions to reach the 1,5℃ goal. According to scientific research, the natural method that shows the biggest potential to mitigate the effects of climate change by taking up CO2 from the atmosphere and subsequently sequestering it is reforestation, the planting of trees in areas from which they have been previously cleared. Because reforestation has a big potential to help mitigate global warming, many countries have incorporated plans to reforest large areas in their NDCs. This research analysed how Costa Rica and Brazil incorporated reforestation in their 2015 NDCs, which actions they took in the five year period after they submitted their plans and corresponding outcomes. It showed that Costa Rica is projected to exceed their reforestation goals, while Brazil has lost significant forest area and seems unlikely to meet their goals. The reason for these different expected outcomes is proposed to be driven by the political landscape in both countries which should provide adequate financial incentives to motivate landowners to reforest their land as an effective mitigation strategy. The outcomes of this research indicate that the political landscape is driving the outcomes of reforestation actions in Brazil and Costa Rica, regarded as a more widespread trend according to the literature. Therefore, this research proposes that to overcome the challenges and achieve the reforestation goals, policy measures should be improved. Providing an adequate financial incentive as motivation for landowners to increase reforestation can be an effective strategy to achieve the reforestation goals as the results of the Costa Rica case indicates. In improving these practices, countries can achieve their NDCs and optimise the amount of CO2 their forest lands can sequester. In this way the effects of climate change can be effectively mitigated and our natural systems protected from the harmful impacts of climate change.

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INTRODUCTION

Climate change is becoming an increasingly urgent matter. If global temperatures continue to rise, we will face serious repercussions, ranging from more extreme weather events and sea-level rise to increased species extinction (IPCC, 2022). Many land and marine ecosystems and some of the services they provide have already shown significant negative changes (IPCC, 2022). The urgency was recently highlighted again in the 2022 Global Risks Report, which declared climate change to be the most severe global problem humanity is currently facing (WEF, 2022). Through such reports, the need to take action has gradually become clearer to policymakers and society as a whole (Bakaki & Bernauer, 2016).

In scientific circles, climate change mitigation has held a prominent place for a longer period of time (Lynas et al., 2021). Over the past few decades, there has been a significant increase in the amount of scientific research on effective ways in which the effects of climate change can be mitigated. To illustrate this, between 2012 and 2020, there were 88,125 climate-related papers published on the Web of Science in the English language, in contrast to 30,627 papers published between 1991 and 2011 (Lynas et al., 2021). Emerging from this ever-growing body of research, there is one number mentioned more than any other on the global podiums of the United Nations climate summit in Glasgow: 1.5°C. This number, as formulated in the Paris Agreement in 2015, is the goal leaders around the world agreed to strive for as the limit for global warming. By limiting the planet's warming to 1.5°C by 2100, the hope is to avoid severe climate disruptions that could lead to drought, hunger, and conflict worldwide (IPCC, 2022).

The <1.5°C strategy relies on the use of negative emission technologies (NET) which can be either technology- or nature-based (IPCC, 2018). These "NETs" are a suite of technologies that aim to reduce the amount of greenhouse gases in the atmosphere through their extraction and subsequent sequestration (McLaren, 2012). Moreover, recent analyses show that deploying NETs may be less costly and disruptive than lowering some emissions, such as a significant share of agricultural, land-use, and transportation emissions (National Academies of Sciences, Engineering, and Medicine et al., 2019).

There are several natural climate solutions with considerable negative emission potential. Examples are avoiding forest conversion or improving grazing pathways in the livestock sector. However, reforestation has the greatest potential as a nature-based negative emissions (NBNE) strategy (Griscom et al., 2017). Reforestation is defined here as "the intentional process of returning trees to areas from which they were previously cleared" (Herbohn et al., 2022). In addition to its potential for storing carbon, reforestation can provide significant co-benefits including enhanced soil fertility, water and air filtration, flood control, and an increase in biodiversity (Griscom et al., 2017). Given the potential of reforestation as an NBNE strategy, countries around the world have made plans to reforest hundreds of thousands of square kilometres as a spearhead strategy in their Nationally Determined Contributions (NDCs) (Brown et al., 2019). These NDCs are submitted to the UNFCCC secretariat every five years with an outline of the countries' climate action. Together they lie at the heart of the Paris Agreement (UNFCCC, 2015). The shift towards more reforestation is reflected in these NDCs, given that 42% of them include reforestation (IUCN, 2019). Numerous countries have set ambitious reforestation goals. For example, China aims to increase its forest stock by 4.5 billion m3, and India aims to increase its forest carbon sink by 2.5 BT CO2 eq. (Brown et al., 2019; Griscom, 2017).

These goals are ambitious and sound promising, yet bear the question of feasibility given that historically, negotiators with limited local knowledge have been responsible for driving them (Schweizer et al., 2019). Wide-scale recognition of pitfalls, such as those of competing land uses, has been suggested to reveal major feasibility flaws in global reforestation maps and national commitments (Holl & Brancalion, 2020). In view of the pressing need for effective mitigation strategies, it is imperative to examine the feasibility of large-scale reforestation as a nature-based solution. An in-depth analysis of case studies and recent data from the most recent NDCs can offer practical illustrations. A given approach is instrumental in offering insights into the feasibility of reforestation targets, as well as the barriers and enabling factors that underpin their success.

One of the countries that is considered to be at the forefront of reforestation efforts is Costa Rica, which is well renowned for its progressive environmental policies and sustainable development. An example of its success in reforestation efforts is seen in the Bonn Challenge, an international goal to restore 350 million hectares by 2030 (Herbohn et al., 2022). In 2019, Costa Rica had already brought a total of 3,031,115.9 ha under restoration (IUCN, 2019). One of the key drivers of their success is their policy and socio-economic approach to reforestation, in which the national government provides financial incentives for reforestation (UNFCCC, 2019). Given their high regard for reforestation and potential to serve as an example for other countries, Costa Rica will be the first case studied in this paper. A second South American country that approaches reforestation differently is Brazil, which will be used as a second case in this paper. Despite sharing progressive reforestation goals like Costa Rica, Brazil adopts a dissimilar policy approach. In contrast to the financial incentive that Costa Rica creates for reforestation, Brazil opts for a strategy that legally mandates reforestation. The divergent strategies employed by these countries to accomplish reforestation goals create an opportunity for an interesting comparative analysis of the two approaches in the search for feasible reforestation targets and strategies.

To conduct a comparative analysis and gain insights, it is necessary to comprehend the context of reforestation. By nature, reforestation is a multidisciplinary process. It is not solely a biophysical process of increasing forest area but concerns a Human-Environment interaction. Moreover, due to the complex nature of socio-economic, biological, and policy drivers, reforestation assessment requires an inherently interdisciplinary approach to a greater degree than other land use conversions (Southworth & Nagendra, 2009). Reforestation is a long term process that can be classified into several stages and therefore considered a continuum (Kanowski and Catterall, 2007). This continuum spans from the successful establishment of initial planting through maturation and the realisation of the socio-economic benefits of the forest (Reay & Norton, 1999). This multidisciplinary nature of reforestation is clearly reflected in the main objectives of reforestation projects, which, according to the CIFOR Rehab Team (2003), are: to enhance productivity, livelihood, and environmental services. Given the fundamentally multidisciplinary nature of reforestation, this paper will adopt a corresponding multidisciplinary approach in which it tracks reforestation efforts from three disciplinary perspectives: biology, policy, and socio-economics. This approach facilitates later integration and interdisciplinary analysis of the 2015-2020 reforestation actions of the two countries as part of the NDCs. In order to synthesise and make theoretical progress, it is essential to integrate specific case studies like these into the broader literature and establish connections between multiple case studies (Southworth & Nagendra, 2009).

First, this study will describe the current NDC reporting procedure and its shortcomings. Then, multiple disciplinary frameworks independent from the UNFCCC used as innovative multidisciplinary analysis tools for NDC progress will be described. Each of these frameworks is based on the 2020 Global Forest Resources Assessment (FRA) by the Food and Agriculture Organisation (FAO).

Using these frameworks, this study will then move on to two case studies of Costa Rica and Brazil, which will be described through the lens of the frameworks. Each case study consists of several components. First, a short overview of relevant historical trends in reforestation is provided. Second, how reforestation is incorporated into the NDC. Third, the frameworks serve as a tool through which the country's 2015-2020 actions subsequent to the 2015 NDC are tracked. Data used for this analysis is gathered from the 2020 FRA country specific reports by the FAO (FAO, 2020d). This data is validated due to the mandatory data check by relevant national authorities, which is usually the head of forestry (FAO, 2020a). For additional analysis of the data and progress tracking, and to fill the gaps of missing data in the FRA database, two widely used online review tools are used: CAT (Climate Action Tracker, December 2019 update) and ClimateWatch. These online tools are specifically designed to track NDC progress and contain data and contextual information from scientific literature about the biological, political, and socio-economic development of the countries.

After the two case studies, this paper will move to a comparison and integration of these case studies. In particular, this part focuses on the identification of underlying drivers that form more widespread barriers and enabling conditions for reforestation. This will be done by comparing the case study results to one another and to trends found in literature. Finally, this paper will end by providing a discussion and conclusion with recommendations for future research and action.

In summary, a multidisciplinary analysis of these two countries can offer valuable insights into their progress and the effectiveness of their reforestation incentives. Additionally, it can serve as a foundation for identifying systemic barriers and enabling conditions that underpin large-scale reforestation initiatives. Therefore, the aim of this paper is to provide an overview and comparison of the reforestation goals, approaches, and outcomes of Costa Rica and Brazil as part of their 2015 NDCs. By adopting the FAO framework, it aims to overcome the current gaps in NDC reporting. The subsequent comparison and integration of the case studies aim to elucidate the systemic impediments and enabling conditions that underlie large-scale reforestation initiatives. These insights could be used in future recommendations regarding reforestation efforts as well as NDC goal setting and reporting, bringing us one step closer to staving off the effects of climate change.

NDC REPORTING

The following section will provide an overview of the current process of NDC reporting and an explanation as to why the FAO framework was adopted in this paper.

To quantify the effectiveness of reforestation, a clear monitoring process is needed to gather data that can be used to calculate trends over time. Under the Paris Agreement, it was set as a precondition that all countries would provide emissions data and track their progress against the submitted NDC (Singh et al., 2016). To do this, the UNFCCC and IPCC provided countries guidance in reporting with a broad prescription for reporting on NDCs based upon so-called "MRV," a system that combines three separate yet connected processes of measurement or monitoring (M), reporting (R), and verification (V) (IPCC, 1996, 2006). Within the requirements and guidance for the MRV methodological basis, countries have considerable flexibility in the methods they use. This led to many countries struggling with the design and implementation of MRV systems, in particular due to technical, institutional, and financial challenges such as a lack of capacity building on good practises for cross institutions collaboration that address and clarify institutional arrangements (Rosenstock et al., 2019). Currently, across countries, NDCs vary extensively in their units of measurement, time frame, and reporting methods, as well as the completeness of the information provided, making it challenging to assess progress and get a global snapshot of how collective mitigation action is going (World Economic Forum, 2022b). Furthermore, there are several important gaps in the reporting under the UNFCCC, such as a lack of transparency in information on the assumptions, conditions, and methods related to the attainment of targets (Ellis & Moarif, 2015)

Given the lack of a common structure and set of rules for reporting mitigation targets, this paper will adopt a framework developed independently from UNFCCC and IPCC prescriptions. The frameworks that will be used will be based on the latest 2020 FRA by the FAO because of its approach that balances biological, policy, and socio-economic objectives (FAO, 2020d). The framework therefore lends itself to being used as a framework for a multidisciplinary analysis. Furthermore, it is based upon the collective effort of not only the FAO itself but also the FAO member countries, institutional and resource partners, and hundreds of experts worldwide (FAO, 2020d). This widespread collaboration increases synergies among reporting processes and improves consistency between country reports, producing a widely applicable and well-documented framework. Furthermore, there are specific requirements to provide definitions that could overcome the transparency gap in current reporting, as well as mandatory annual reporting on several criteria which was implemented beginning in 2015 to fulfil reporting requirements for the Sustainable Development Goals (SDGs), increasing data availability to deduce trends. As this paper also aims to identify more widespread barriers and enabling conditions when it comes to NDC achieveability, using a framework that can be applied globally allows for replication as well as widespread applicability for case studies of other countries.

The FAO report is structured around different "themes", of which each have a number of indicators associated with them to enable quantification. Due to its equal prompt nature, it helps improve consistency, comparability, and completeness of the information reported. For these reasons, this format will be adopted to compare the two case studies. For this paper, the themes and indicators have been divided based on the discipline they belong to to create three separate frameworks. This is done to generate a structured summary per discipline that facilitates comparison of multiple case studies. Furthermore, an extra prompt was added that considers the total change over the 2015-2020 time period. This facilitates the visualisation of trends in the first five year period after submitting the NDCs. The blank frameworks are described in Appendix A. This paper will now move to the specifications for the FAO framework indicators used in this study.

FRAMEWORK INDICATOR SPECIFICATIONS

This section provides an overview of the specifications of the indicators used in the frameworks for quantification in the two case studies. All of these indicators relate to reforestation by reflecting one of the three main objectives of reforestation projects. The indicators and their specifications, as reprinted from the FRA guidelines and specifications report, are described in tables 1-3.

Table 1: Biology indicator specifications

This table shows an overview of the indicators in this study, these are reprinted from the FAO guidelines and specifications report underpinning the 2020 FRA (FAO, 2020a).

Theme	Indicator	Specification
Forest extent and changes	1a Extent of forest and other wooded land	Forest and other woodlands based on FAOSTAT (the system validation rule). Annual reporting has been introduced starting from 2015 in order to meet reporting requirements for the Sustainable Development Goals (SDGs), facilitating data recovery for the extent of forests and other wooded land.
	1b Forest Characteristics	Plantation forest and other planted forest, together as planted forest.

	1c Annual forest expansion	Sum of afforestation and natural expansion.
	1d Annual reforestation	Average reforested area for the given reporting period.
	1e Other land with tree cover	Sum of area occupied by palms, tree orchards, agroforestry, and trees in urban settings.
Forest growing stock, biomass and carbon	2a Growing stock	Total growing stock of Naturally Regenerating forest, Plantation forest, other planted forest, and other wooded land. In order to allow annual calculation of biomass for reporting to the SDGs, growing stock has also been reported annually from 2015 onwards.
	2b Biomass stock	Forest biomass consists of above ground biomass and below ground biomass through biomass conversion and expansion factors.. In order to allow annual calculations of biomass and carbon for reporting to the SDGs, also biomass stock is reported annually from 2015 onwards.
	2c Carbon stock	Carbon in above ground biomass and carbon in below ground biomass, derived using conversion factors.
Forest disturb ances	3a Area affected by fire	Total forest area affected by fire.
	3b Degraded forest	For this indicator, no data input is required. It concerns a description (if existing) of degraded forest and, in case a monitoring process is in place at the national level, a brief description of methodology and results.

Table 2: Policy indicator specifications

This table shows an overview of the indicators, these are reprinted from the FAO guidelines and specifications report underpinning the 2020 FRA (FAO, 2020a).

Theme	**Indicator**	**Specification**
Forest designation and management objective	1a Designated management objective	Management objectives (primary) of forest area: production, protection of soil and water, conservation of biodiversity, and multiple use.
	1b Forest area within legally established protected areas and forest area with long-term forest management plan	Forest area within legally established protected areas and forest area with long-term forest management plan. For this indicator too, annual reporting has taken place since 2015 in order to meet the requirements for the Sustainable Development Goals (SDGs).
Forest ownership and management rights	2a Forest ownership: Public	Forest area with public ownership.
	2b Forest ownership: Private	Individual ownership, ownership by private business entities and institutions, and ownership by local, tribal, and indigenous communities.
	2c Management rights of public forest	Public administration, individuals, private business entities, and institutions, local, tribal, and indigenous communities.

Forest policy and legislation	3a Policies, legislation and national platform for stakeholder participation in forest policy	This indicator does not require data input. Here, national correspondents report (boolean style, yes/no) on the existence of policies supporting SFM, legislation and/or regulations supporting SFM, and a platform that promotes or allows for stakeholder participation in forest policy development, and a traceability system for wood products.
	3b Area of permanent forest estate	Area of permanent forest estate.

Table 3: Socio-Economic indicator specifications
This table shows an overview of the indicators, these are reprinted from the FAO guidelines and specifications report underpinning the 2020 FRA (FAO, 2020a).

Theme	**Indicator**	**Specification**
Employment, education and NWFP	1a Employment in forestry	Consisting of employment in silviculture and other forestry activities, the gathering of non wood forest products, and support services to forestry. reported in full time equivalents (one full time employee counts as one FTE, and two half-time employees also count as one FTE). If the breakdown of FTE by gender is available, the National Correspondents can report this too.
	1b Graduation of students in forest-related education	Doctoral degree, master's degree, bachelor's degree, and technical certificates and diplomas. If the breakdown by gender is available, the National Correspondents can report this too.
	1c Non wood forest products removals and value 2015	Removals and values of non wood forest products values are reported in 1000 local currencies and assigned a corresponding FAO non wood forest products category.

This paper will now move to the case studies. For each case study, it will first provide a short description of historical trends and the development of current reforestation practises. Then, it will describe the reforestation goals set in the 2015 NDC and move on to an analysis of the actions in the following five year period using the three disciplinary frameworks.

CASE STUDY 1: COSTA RICA

HISTORY

Over the last couple of decades, Costa Rica has established itself as a pioneer in the search for alternative methods of reducing CO2 emissions by means of reforestation (ClimateWatch, 2015b). This has led to the creation of a a variety of political tools, both for mitigation and adaptation. This is remarkable given that only a few decades ago, in 1987, Costa Rica had lost almost half of its forest area as a result of deforestation (UNFCCC, 2019). Then, in 1996, a new forest law was promulgated, which laid the foundation for the present forestry policy (Climate-Laws, 1996). Within this new law, Costa Rica encompassed several fundamental concepts and introduced new systems, such as PES (Payments for

Ecological Services). This system pays landholders for their environmental services, therefore providing an economic incentive for reforestation. It makes direct cash transfers to private landowners for 5 or 10-year contracts for different activities of forest protection, reforestation, sustainable forest management, and agroforestry (UNFCCC, 2019). According to FONAFIFO, the national forestry finance fund, the PES scheme pays an average of $64 per hectare per year for basic forest protection (Konyn, 2021). The PES system is funded by fuel and water taxes levied by Costa Rica, as well as by its own efforts, including carbon credits, certificates of biodiversity conservation, and joint ventures with the public and private sectors (UNFCCC, 2019). A combination of a ban on deforestation combined with the introduction of this PES- system caused the country to become the first tropical country to have stopped and then managed to reverse deforestation, meaning surpassing the point to net gain in forest area by means of reforestation (UNFCCC, 2019).

Two other projects have been shaping Costa Rica's history in reforestation. First, the Guanacaste Conservation Area, which is an area of 163,000ha of land under the administration of the Sistema Nacional de Áreas de Conservación (SINAC), which is part of the Ministry of Environment and Energy of Costa Rica. This initiative was founded in 1986 with the mission to restore forests and surrounding ecosystems that have suffered destruction caused by human action (SER, n.d.). As a result, approximately 70,000 ha of previously cleared forest area are now covered with regenerating forest again as a result of seedling recruitment from adjacent stands of pristine forest (SER, n.d.). Second, the BaumInvest reforestation project, which launched in 2007 (Gold Standard, n.d.). As a result, about 1280 ha of pastureland have been reforested, and over a million native trees have been planted (Gold Standard, n.d.). Furthermore, the country has a world renowned protected area network covering over a quarter of the national territory (Southworth & Nagendra, 2009),

Thus, Costa Rica has a rich history in reforestation action and projects which given their success suggest a tight collaboration between disciplines. This paper will now move to the 2015 NDC reforestation goals for Costa Rica.

REFORESTATION OBJECTIVES

In September 2015, the Costa Rican government submitted its first NDC to the UNFCCC (Gobierno de Costa Rica, Minesterio de Ambiente y Energía, 2015). Regarding reforestation, it states that:

1. Costa Rica is committed to develop its adaptation practice from an ecosystem based adaptation focus, building on the readily existing commitment from the National Plan for Carbon Neutrality to increase the total forest cover area to 60% by 2030.
2. Costa Rica is committed to a maximum of 9,374,000T CO2 net emissions by 2030's. This transition into a resilient and low emissions economy is based upon 4 main mitigation options of which one is 'enhancing carbon sinks' by means of land-use change and **reforestation**.

Thus, Costa Rica mentions the importance of reforestation multiple times in their NDCs and is committed to improving and growing its reforestation efforts within the 2015-2020 time period. Furthermore, there is a section dedicated to describing all departments and councils involved in the implementation of these goals. This includes a total of five separate entities (ClimateWatch, 2015b). The NDC specifically states that "The potential emission reduction in the forestry sector is lower than the previous estimates due to the country's forest being mainly mature forests with high carbon stocks, and lower carbon fixing capacity " (Gobierno de Costa Rica, Minesterio de Ambiente y Energía, 2015).

A BIOLOGICAL PERSPECTIVE

Having considered Costa Rica's historical trends in reforestation and its set NDCs, we now move to the data considering Costa Rica's actions in the 2015-2020 time period from a biological perspective, presented in table 4. These indicators specifically focus on spatial and biophysical data such as forest area, carbon stock, and possible forest disturbances gathered from the country specific report as part of the 2020 FRA.

Framework analysis

Table 4: Biology Framework Costa Rica

This table shows an overview of the data on Costa Rica in the 2015-2020 period based on the country report as part of the FRA (FAO, 2020c).

Title	**Indicator**	**Unit**	**Reporting year**					
			2015	**2016**	**2017**	**2018**	**2019**	**Total change**
Forest extent and changes	1a Extent of forest and other wooded land	1000 ha	2953.03	2969.40	2985.77	3002.13	3018.50	+65.47
	1b Forest characteristics: Planted forest	1000 ha	76.6	78.6	80.6	82.6	84.6	+8
	1c Annual forest expansion	1000 ha/year	N.A.	N.A.	N.A.	N.A.	N.A.	+16.37
	1d Annual reforestation	ha/year	2330,2	2271,3	2002,5	2002,5	2002,5	2110 average per year
	1e Other land with tree cover	1000 ha	462.54	N.A.	N.A.	N.A.	N.A.	N.A.
Forest growing stock, biomass and carbon	2a Growing stock	m3/ha Million m3	774.61	778.61	782.63	786.65	790.64	+12.99
	2b Biomass stock	tonnes/ha	248.4	248.4	248.4	248.4	248.4	0
	2c Carbon stock	tonnes/ha	124	124	124	124	124	0
Forest disturbances	3a Area affected by fire	1000ha	2.00	25.82	6.93	N.A.	N.A.	n/a
	3b Degraded forest	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	-

Data interpretation

Forest extent and changes

The dataset shows a yearly increase in forest cover in Costa Rica, with no years depicting any decrease. The total change over the five year period shows an increase of 65470 ha. Of this total increase in forest area, 8000 ha are considered planted forest rather than naturally regenerating forest. No specific information about which species make up this planted forest is available. It is important to define whether we are dealing with planted forests or naturally regenerating forests, because planted forests have a different ecology and associated environmental impacts in comparison to natural forests. This ranges from potential negative impacts below ground, such as on soil fertility, to above ground impacts on biodiversity (Liao et al., 2011). Research shows, for example, that natural forests sequester more carbon than planted forests (Yu et al., 2018). Furthermore, large scale planting of forests could also lead to problems such as significant water yield reduction due to higher water consumption or decreased soil fertility (Liao et al., 2011; Yu et al., 2018). Therefore, it is important to specify whether a country's reforestation involves planted forests or the restoration of natural forests if we aim to maintain the ecosystem sustainably.

In the case of Costa Rica, the indicated planted forest specifically considers forest plantations, which are specifically defined in their report as follows: “According to Forest Law 7575, a forest plantation is a piece of land of one or more hectares cultivated with one or more forest species whose main objective, although not necessarily the only one, is the production of wood. In satellite images and aerial photos of high resolution, these can be identified by their homogeneous texture.”

Annual forest expansion in the given time period shows a net change rate of 16.37, which is a positive value reflecting the gain in forest area. This also means that deforestation is smaller than forest growth. Annual reforestation shows steady numbers over the years, with an average yearly reforestation of 2121.8 ha. An extra comment in the report regarding data sources states that this reforestation is done as part of the PES-system and monitored by FONAFIFO. Furthermore, it is stated that the same definition of reforestation is adopted as in this paper. There is no further specification available in the report in regards to which species are used for reforestation. Other land with tree cover, including palms, tree orchards, agroforestry, and trees in urban settings, does not have sufficient data available in the FAO database to be able to calculate trends over time.

Forest growing stock, biomass and carbon

The total growing stock consists of naturally regenerating forest combined with planted forest, the ratio of these two components is shown in table 5. This growing stock shows a yearly increase, in line with the above data on natural and planted forest expansion. As can be seen, the proportion of growing stock is much higher in natural forests in comparison to planted forests. Furthermore, the increase in the growing stock of natural forests is also quicker than that of planted forests. Biomass and carbon stock show no significant change in numbers over time, the report states that this is because there is an absence of historical data. For this reason, they filled in the carbon stock data per pool according to an IPCC report from 1977 for each year. Therefore, we cannot deduce trends over the total time period.

Table 5: FAO data on total growing stock of Costa Rica

This figure shows an overview of the data on growing stock in Costa Rica, reprinted from the country data reports as part of the 2020 FRA (FAO, 2020c).

Categories	**Total growing stocks (millions of m3 above-ground)**				
	2015	**2016**	**2017**	**2018**	**2019**
Naturally regenerating forest	768.01	771.84	775.68	779.51	783.35
Planted forest	6.60	6.78	6.95	7.12	7.29

Forest disturbances

The data on forest fires show that there is considerable forest area lost as a result of forest fires, especially in 2016 with a peak of 25815,97 ha of forest lost to fires. In regards to degraded forests, there is a national definition formulated for what is considered a degraded forest, yet there is no monitoring process or results reported. In the report, Costa Rica comments on this, stating that although the country does not have a specific monitoring programme for degraded forests, their definition is based on reports by the FCPF-REDD Plus (Reduction of Emission from Deforestation and Degradation). Therefore, no insight can be provided into the proportion of forest area that is degraded.

A POLICY PERSPECTIVE

This case study now moves to a policy perspective on Costa Rica's 2015-2020 reforestation actions. These indicators focus on land area measurements as part of policy objectives, as described in table 6. The data is gathered from Costa Rica's country specific report as part of the 2020 FRA.

Framework analysis

Table 6: Policy Framework Costa Rica

This table shows an overview of the data on Costa Rica in the 2015-2020 period based country report as part of the FRA (FAO, 2020c).

Title	**Indicator**	**Unit**	**Reporting year**					
			2015	**2016**	**2017**	**2018**	**2019**	**Total change**
Forest designation and management objective	1a Designated management objective	1000ha	2 953.03	N.A.	N.A.	N.A.	N.A.	+81.84
	1b Forest area within legally established protected areas and forest area with long-term forest management plan	1000ha	1706.23	1722.6	1738.79	1756.32	1771.7	+65.47
Forest ownership and management rights	2a Forest ownership: Public	1000ha	1265.7	N.A.	N.A.	N.A.	N.A.	-
	2b Forest ownership: Private	1000ha	1402.93	N.A.	N.A.	N.A.	N.A.	-
	2c Management rights of public forests	1000ha	1265.7	N.A.	N.A.	N.A.	N.A.	-
Forest policy and legislation	3a Policies, legislation and national platform for stakeholder participation in forest policy	N.A.	Data described in the data interpretation section due to boolean style reporting.					
	3b Area of permanent forest estate	1000ha	1265.7	N.A.	N.A.	N.A.	N.A.	N.A.

Data interpretation

Forest designation and management objective

The forest area with a primary management objective shows an increase of 81840 ha (start of 2020 data minus 2015 data). This considers areas dedicated to production, conservation of biodiversity, and multiple uses, of which the only one showing an increase is multiple use, meaning the forests are managed for multiple designated functions, such as a combination of biodiversity conservation with soil and water protection. The other two management categories have remained constant over time.

The forest area within legally protected areas and with long-term management plans has increased by 62470 ha, of which both the forest area in protected areas and those with long-term management plans show similar increase rates.

Forest ownership and management rights

For forest ownership as well as holders of forest management rights, there is only data available for the year 2015. The other years have not been registered.

Forest policy and legislation

Regarding policies, legislation, and a national platform for stakeholder participation in forest policy, Costa Rica has indicated the national existence of policies supporting Sustainable Forest Management (SFM), legislation and regulations supporting SFM, platforms that promote or allow stakeholder participation in forest policy development, and traceability systems for wood products. These are essential for successful and sustainable forest emerging from reforestation and other forest area expanding drivers. For each of the givens, it has been indicated that no sub-national ones exist, meaning current efforts are mainly a strategy at the national level.

Supplementary data collection demonstrates a number of policy developments in the time period, such as the introduction of several measures to speed up the implementation of the NDCs, such as the official start of the second phase of the National Plan for Carbon Neutrality (which first set the 60% forest coverage goal) (CAT, 2019b). Costa Rica is dependent on sinks in the LULUCF (Land Use, Land-Use Change, and Forestry) sector to meet its carbon neutrality goal; therefore, there is a strong link between reforestation action and policy that serves the carbon neutrality goal. Due to the usage of Costa Rican Compensation Units (UCC in Spanish), this has so far been successful. They serve as a representation of the monitored and verified avoided, reduced, eliminated, and stored emissions. Domestically, the units can be traded on a voluntary basis (Ministerio de Ambiente y Energía and Presidente de la República, 2017; Salgado et al., 2013).

A SOCIO-ECONOMIC PERSPECTIVE

This case study now moves to a socio-economic perspective on Costa Rica's 2015-2020 reforestation actions, described in table 7. These indicators focus on numbers of employment and education to consider the social angle and currency values for an economic perspective on reforestation. The data is gathered from Costa Rica's country specific report as part of the 2020 FRA.

Framework analysis

Table 7: Socio-economic Framework Costa Rica

This table shows an overview of the data on Costa Rica in the 2015-2020 period based country report as part of the 2020 FRA (FAO, 2020c).

Title	Indicator	Unit	Reporting year					
			2015	**2016**	**2017**	**2018**	**2019**	**Total Change**
Employment, education and NWFP	1a Employment in forestry	1000 years full-time equivalents	14.81	N.A.	N.A.	N.A.	N.A.	-
	1b Graduation of students in forest-related education	Number	30	29	31	N.A.	N.A.	n/a
	1c Non wood forest products removals 2015	Value: 1000 local currency Quantity: local unit	N.A.	N.A.	N.A.	N.A.	N.A.	-

Data interpretation

Employment, education and NWFP

Regarding employment in forestry, there is only data available for the year 2015. Graduation of students is also only available for one university, the national one. However, what the report notes in the comments is that, as of 2018, 978 forestry professionals are reported at different academic levels. These, however, could not be separated into the ranges that are required because the information provided by each academy was in different periods and formats. Lastly, no data is available about non wood forest product removals and value, on which the report states that there are no reliable records of the extraction of non-timber products from the forest.

ADDITIONAL TRENDS & RELATION TO NDC

What can be drawn from this analysis is that, especially from a biological perspective, the country has made great progress, as illustrated by the increase in forest area cover. The total forest area as a proportion of the total land area has grown from 57.83 to 59.12% in the 2015-2020 period, meaning the 60% forest cover by 2030 goal that was set in the 2015 NDC was already almost reached within the first five years (FAO, 2020d). Furthermore, the FAO data on both policy and socio-economic indicators was lacking. Additional sources showed several policy developments in the time period that suggest reforestation as a mitigation practice has been successful from a policy perspective. However, the lack of data prevents quantification and the visualisation of trends in this regard.

Given the lack of information on socio-economic benefits related to reforestation, according to the FAO report, CAT and Climate Watch data, no conclusions or interpretations can be provided about the socio-economic impacts of the reforestation efforts of the time period.

Nevertheless, summarised, Costa Rica seems to have made great progress towards reaching the reforestation specific goals that were stated in its NDC related to reforestation. According to CAT, Costa Rica is even on track to exceed its 2030 NDC (CAT, 2019b; FAO, 2020b).

CASE STUDY 2: BRAZIL

HISTORY

As stated in the 2015 NDC report by the Brazilian government, "Brazil is a developing country and, as such, struggles with challenges associated with poverty eradication and the need to improve its development indexes in areas that include education, public health, employment rates, housing, and social inclusion. Furthermore, as a developing country, Brazil faces the challenge of contributing to the global efforts to mitigate emissions, according to the principle of common but differentiated responsibilities, and at the same time implementing adaptation actions to cope with the impacts of climate change in its territory". This short segment from the NDC captures the current state in which the country resides.

In its history, Brazil has experienced a significant area forest loss (Wiltshire et al., 2022). In 1934, to combat deforestation, the Brazilian government implemented a new policy strategy to ensure reforestation efforts (WeForest, 2021). Rural landowners are required by law to restore riparian forests on their lands and, depending on farm size, an addition known as the "Legal Reserve." The procedures underpinning this technique that aid in promoting compliance and enforcement were improved by a subsequent revision of this statute in 2012 (Schweizer et al., 2019). However, this amendment significantly reduced the areas that need restoration and controversially gave amnesties to landowners who disregarded their restoration duties (Brancalion et al., 2016). According to the revision, landowners must declare any sections of their property in need of restoration in order to qualify for rural bank financing. Landowners have the option to enrol in a restoration programme on or off their properties after declaring. The latter method allows landowners to lease or buy natural vegetation-covered land from another owner in the same biome. This gives the landowners some flexibility but also creates the risk of leaving areas such as important watersheds unprotected (Brancalion et al., 2016). This mandate now shows to be the main restoration driver, making reforestation in Brazil heavily reliant on political will (Schweizer et al., 2019). This paper will now move on to the 2015 NDC reforestation goals from Brazil and the analysis of their actions in the following years.

REFORESTATION OBJECTIVES

In September 2016, Brazil submitted its NDC, in which they 'intend to commit' to reduce greenhouse gas emissions by 37% below 2005 levels in 2025. In regards to reforestation specifically, they set the goal of restoring and reforesting **12 million hectares of forest by 2030** (Federative Republic of Brazil, 2016).

In regards to the institutions involved in the realisation of these goals, the Brazilian Forum on Climate Change serves as the conduit for institutional communication between the Brazilian government and civil society (ClimateWatch, 2015a).

A BIOLOGICAL PERSPECTIVE

Framework analysis

Table 8: Biology Framework Brazil

This table shows an overview of the data on Brazil in the 2015-2020 period based country report as part of the FAO 2020 FRA (FAO, 2020b).

Title	Indicator	Unit	Reporting year					
			2015	**2016**	**2017**	**2018**	**2019**	**Total change**
Forest extent and changes	1a Extent of forest and other wooded land	1000 ha	543396.5	541431.2	539282.3	538081.9	536670	-6726.5
	1b Forest characteristics: Planted forest	1000 ha	9937.90	10023.10	9839.7	10503.3	10863.5	+925.6
	1c Annual forest expansion	1000 ha/year	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
	1d Annual reforestation	1000 ha/year	N.A.	N.A.	N.A.	N.A.	N.A.	257.13
	1e Other land with tree cover	1000 ha	292417.50	N.A.	N.A.	N.A.	N.A.	N.A.
Forest growing stock, biomass and carbon	2a Growing stock	m3/ha Million m3	121608.52	121274.9 8	120895.1 8	120755.3	120550. 5	-1058.0 2
	2b Biomass stock	tonnes/ha	211.69	211.91	212.13	212.36	212.54	+0.85
	2c Carbon stock	tonnes/ha	104.2	104.3	104.4	104.5	104.58	+0.38
Forest disturbances	3a Area affected by fire	1000ha	32998.07	26605.07	29609.36	N.A.	N.A.	n/a
	3b Degraded forest	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	-

Data interpretation

<u>Forest extent and changes</u>

When looking at the total area of forests and other wooded land, described in table 8, we see a 6726500 ha decline in the 2015-2020 time period. Furthermore, there has been an increase in the area of planted forest, which is almost of the same magnitude as the annual reforestation. Planted forest is described in the Brazilian FAO report as “Forest predominantly composed of trees established through planting and/or deliberate seeding." It is distributed all over the country’. This is not further specified, leaving it unclear what further requirements planted forests need to meet, for example, in regards to which species ought to be used, which locations they can be planted, or if this can be anywhere. As illustrated in table 9, all of the planted forest in this case is considered plantation forest, for which no formal definition is provided. Therefore, there is also no information regarding the location of these plantation forests or the possible impacts this has on surrounding areas.

Table 9: FAO data on forest characteristics in Brazil

This table shows an overview of the extra data on the forest characteristics of planted forests in Brazil in the 2015-2020 period. Reprinted from the data reports as part of the 2020 FRA (FAO, 2020b). Highlighted in red is the proportion of introduced species in planted forests.

FRA categories	**Forest area (1000 ha)**				
	2015	**2016**	**2017**	**2018**	**2019**
Naturally regenerating forest (a)	493 946.80	492 058.90	490 251.90	488 548.00	486 935.00
Planted forest (b)	9 937.90	10 023.10	9 839.70	10 503.30	10 863.50
Plantation forest	9 937.90	10 023.10	9 839.70	10 503.30	10 863.50
… of which introduced species	9 510.20	9 622.90	9 431.80	10 062.80	10 405.50
Other planted forest					
Total (a+b)	503 884.70	502 082.00	500 091.60	499 051.30	497 798.50
Total forest area	503 884.80	502 082.10	500 091.60	499 051.40	497 798.50

When taking a closer look at the data and analysing the additional data available for this indicator in the FRA country report,, we can see that a large proportion of this plantation forest considers introduced species. The elaborated data in table 10 on annual reforestation shows the large proportion of Eucalyptus or Pinus, which make up the large majority of reforested species. Important to note is that reforestation by means of large numbers of Eucalyptus and Pinus plantations can have significant ecological impacts such as decreased biodiversity and increased soil exhaustion (Da Silva Alves Saccol et al., 2017). Furthermore, there have been cases in which social and economic problems have arisen in Brazil, such as increased poverty, displacing communities, disruption of local markets, and increased conflict (Andersson et al., 2016; Kröger, 2014; Gerber, 2011).

This could potentially mean that the reforestation that has taken place as plantation forest could have some sustainability and ecosystem risks that were previously described in the Costa Rica case study, but in addition also some risks associated with the species that have been used to reforest. Thus, there is a 6726500 ha decline in the total forest area, which would be even more if planted forests of introduced species were left out.

Table 10: FAO data on annual reforestation in Brazil

This table shows an overview of the original extra data on annual reforestation in the 2015-2017 time period in Brazil, (FAO, 2020b)

Year	**Eucalyptus (ha)**	**Pinus (ha)**	**Other Species (ha)**
2015	7.444.625,00	2.065.560,00	427.762,00
2016	7.543.707,00	2.079.162,00	400.207,00
2017	7.411.276,00	2.030.419,00	410.025,00

On reforestation, there is no other data available other than a yearly average of 257130 ha in 2015-2020, which is calculated by means of a linear projection done by the FAO based on 2015-2017 data. There is no definition provided as to the requirements reforestation practises need to meet.

Data from additional data sources to fill in the gaps of the FAO database stated that deforestation in the Amazon region of the country led to Brazil reaching the point in 2018 of losing the most tropical primary rainforest of any nation, amounting to 1.3 million hectares in total (CAT, 2019a). According to national estimates, total deforestation reached 7,900 km2 in 2018 alone, up 13.7% from 2017 levels and 72% from the historic low set in 2012 (CAT, 2019a).

Forest growing stock, biomass and carbon

In line with the declining forest area, the total growing stock shows a decline. The biomass and carbon stocks both show a minor increase. This increase might seem hopeful, but elaborated data reports from the 2020 FRA show that the total growing stock decreases in every natural forest category, together encompassing the forests in all six Brazilian biomes (Amazonia, Caatinga, Cerrado, Atlantic Forest, Pampa, Pantanal). The only significant increase in total forest growing stock can be seen in planted forest, which grows from 2706,44 million m3 in 2015 to 2958,50 million m3 in 2019. The same goes for above- and below-ground biomass and above-and below-ground carbon, plummeting in all natural forest categories and rising in planted forests.

Forest disturbances

In the 2015-2017 time period, there has been considerable forest area lost as a result of fires. There is no data available for the years following this period in the FAO database. When it comes to degraded forests, there are two systems of degraded forest monitoring described in the report. DETER and DEGRAD. DETER monitors the changing forest cover in the legal Amazon on a nearly daily basis. DEGRAD produced data for the 2007-2013 period. These methods are important as the maps generated by these systems provide information about the effectiveness of actions that combat deforestation in the region. Such efforts are guided and planned based on this dataset. Even though this is explicitly mentioned in the FAO report, there is no data resulting from these systems stated in the report.

There is no further information regarding disturbances available in the FAO database. Additional sources state that the 2019 dry season broke records in deforestation and forest fires, which became worldwide news (CAT, 2019a). This is notable because weather patterns were gentler than in prior years, indicating an increase in anthropogenic causes, such as illegal deforestation (CAT, 2019a).

A POLICY PERSPECTIVE

Framework analysis

Table 11: Policy Framework Brazil

This table shows an overview of 2015-2020 data of Brazil from the country report in the 2020 FRA (FAO, 2020b).

Title	Indicator	Unit	Reporting year					
			2015	**2016**	**2017**	**2018**	**2019**	**Total change**
Forest designation and management objective	1a Designated management objective	1000ha	438588.47	N.A	N.A.	N.A.	N.A.	N.A.
	1b Forest area within legally established protected areas and forest area with long-term forest management plan	1000ha	143329.05	145619.35	145679.65	147226.61	148401.91	+5072.86
Forest ownership and management rights	2a Forest ownership: Public	1000ha	281102.41	N.A.	N.A.	N.A.	N.A.	-
	2b Forest ownership: Private	1000ha	222782.39	N.A.	N.A.	N.A.	N.A.	-
	2c Management rights of public forests	1000ha	281102.41	N.A.	N.A.	N.A.	N.A.	-
Forest policy and legislation	3a Policies, legislation and national platform for stakeholder participation in forest policy	N.A.	Data described in the data interpretation section due to boolean style reporting.					
	3b Area of permanent forest estate	1000ha	297998.59	N.A.	N.A.	N.A.	N.A.	-

Data interpretation

Forest designation and management objective

There is insufficient data available to calculate a trend in the management area. What we see in forest areas within protected areas and in forest areas with long-term forest management plans, however, is an increase, described in table 11. Furthermore, all the forest in protected areas does (naturally) also have a long-term forest management plan, as protected areas have management plans associated with them. Thus, the network of protected areas is expanding within Brazil.

Forest ownership and management rights

For the total forest area under public ownership, there is only data available for the year 2015, therefore, no trends over time can be calculated.

Forest policy and legislation

In regards to policies, legislation, and national platforms for stakeholder participation in forest policy, Brazil has provided extensive information on national and subnational policies that support SFM, legislation and regulations that support SFM, platforms that promote or allow stakeholder participation in forest policy development, and traceability systems for wood products. For each of these separate sections, there are national classifications and definitions given, as well as a provided timeline on the development of all legislation and laws. There is too little data available about the area of permanent forest estate to be able to calculate trends over time.

A SOCIO-ECONOMIC PERSPECTIVE

Framework analysis

Table 12: Socio-economic Framework Brazil

This table shows an overview of the data on Brazil in the 2015-2020 period based country report as part of the 2020 FRA (FAO, 2020b).

Title	**Indicator**	**Unit**	**Reporting year**						
			2015	**2016**	**2017**	**2018**	**2019**	**2020**	**Total Change**
Employment, education and NWFP	1a Employment in forestry	1000 years full-time equivalents	79.18	N.A.	N.A.	N.A.	N.A.	N.A.	-
	1b Graduation of students in forest-related education	Number	2106	N.A.	N.A.	N.A.	N.A.	N.A.	-
	1c Non wood forest products removals 2015	Value: 1000 local currency Quantity: local unit	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	-

Data interpretation

In regards to employment, education, and NWFP there is no data available for the given time period in Brazil, as visualised in table 12. The only year in which all three reported was 2015. In the years before, a lot of data was collected on this, which is also extensively described in the report, but from 2015 onwards, this stopped for reasons that could not be found.

ADDITIONAL TRENDS & RELATION TO NDC

When comparing the data with the NDC goal, which set out to restore and reforest 12 million hectares of forest by 2030, it is clear that the course towards achieving this has not run accordingly. In the first five years since this plan was set, the forest area has shown a significant decrease. Baring the question whether the goal of 12 million is still achievable by 2030. Brazil will not meet its set goals if current trends continue. Brazil's actions are therefore marked as “insufficient” in the climate action tracker, meaning they are not consistent with holding warming below 2 degrees Celsius, let alone meeting the Paris Agreement’s stronger 1.5 degree limit (CAT, 2019).

Under the then existing policies, it was anticipated that Brazil would reach emissions levels (excluding LULUCF) of 1,056 MtCO2e by 2025, which is 25% over 2005 levels (CAT, 2019a). Since the then-current administration had not put any new regulations in place to stop the increase in emissions, it was anticipated that emissions would continue to climb in the majority of sectors at least until 2030 (CAT, 2019a). At the time, the Bolsonaro administration continued to weaken environmental institutions with the support of 'ruralist' legislators that have historically opposed forest protection policies. This included significant budget cuts that significantly lowered Brazil's capacity to monitor, inspect, and prevent environmental crimes like illegal deforestation (CAT, 2019a).

The trend over the previous ten years had reversed with the surge in deforestation. This net increase in loss of forest area also relates to emission levels, as the decrease in forest area causes increased emission levels due to lowered sequestration capacity. Local officials stated they lacked the means to stop illicit deforestation over the entire national territory (Messias, 2017). Spending cuts have negatively impacted the ability of national agencies to enforce the law. For example, more than 50% of the Environment Ministry's budget was reduced by the government in 2017, with more cuts following in the years thereafter (Darby, 2017). The National Institute for Space Research (INPE), which is in charge of monitoring Amazonian deforestation through satellite, has also seen a budget drop of roughly 70% over the last seven years. Several even more drastic budget cuts were made during the 2019 administration (CAT, 2019a):

Thus, Brazil's capacity to oversee, monitor, and stop environmental crimes has been significantly diminished by these changes. In addition, not only did authorities' ability to enforce laws decrease, but the government also began to roll back already-enacted LULUCF regulations. The administration signed legislation that would end the protection of 349,000 hectares of National Forest by regularising more unlawful land-grabbing actions (Maisonnave, 2017). Deforestation practices outweigh the reforestation effort which causes the ultimate decline in forest area and surge in emissions. Nevertheless, what we can see in this data in regards to reforestation is that gross levels and numbers of reforestation do suggest that there is the potential and capacity to scale reforestation efforts as a NBNE and hereby reduce emissions.

In summary, key environmental measures have been reversed and environmental institutions have been weakened under Bolsonaro's administration. CAT stated that even though it is difficult to forecast how these regulatory changes will affect emissions, the majority of them have the potential to increase deforestation and other environmental violations. These deforestation rates outweighed the sequestration and area increases in the capacity of reforestation in this dataset, but they do provide insight into their potential.

INTEGRATION: TOWARDS A COMPREHENSIVE UNDERSTANDING

This paper has analysed the course of action in reforestation after 2015 NDC goal setting for two different countries and shown their developments with regards to the goals. In this section, it will move on to analysing the underlying drivers of these outcomes as well as the similarities and differences between cases. Furthermore, it will identify general pitfalls and enabling conditions and see what wide-scale lessons we can take from these two practical examples.

From a biological perspective, which focused on spatial and biophysical data, the cases showed a contrast in the way both countries incorporated reforestation into their NDCs as well as their subsequent actions. Costa Rica continues its successful history in reforestation and shows that further improvements are still being made. Furthermore, the data seem to suggest that competing land uses are not yet a limiting factor, as reforestation still has available area to expand, as reflected in the increased forest area. In contrast, Brazil showed a decrease in forest area and increasing emissions, which corresponded to deforestation numbers. Moreover, the area that was reforested consisted mostly of planted forest with introduced species, which has a potentially lower sequestration capacity in comparison to natural forest and could bring several negative ecosystem and socio-economic impacts with it.

What complicates the biological comparison is the fact that both countries use a different definition of what “planted forest" means. Costa Rica defines it as solely forested land that is used for wood harvest in monocultures, which can be identified by satellite images. Brazil, however, has a less stringent definition, which does not define the exact location or composition requirements for forest to be considered planted forest. If this is indeed the case, this could have further, potentially harmful consequences in regards to ecology as well as sequestration. Not only does this highlight the need for unity in definitions, especially when considering international goals, it also emphasises the importance of which reforestation methods are used, and that data can create a conflicting view of the reality of reforestation. Planted forests with invasive species increase in area in large numbers in the dataset, and are the numbers communicated to all FRA readers, but could be an unsustainable solution given their potentially harmful ecological impacts as well as lowered capacity for sequestration, needed to reach mitigation goals (Yu et al., 2018).

What we see in both cases is that the biological data is merely the output generated by the input the political and socio-economic landscape provides, meaning the leading driver of reforestation seems to be policy measures (and the incentives they do or do not create). The Brazil case shows that when funding and legislation are cut, narrowed, or limited, the outcomes in terms of reforestation area and carbon stocks will reflect this. This matches the narrative of the 2019 interview-based research by Schweizer et al., which showed the Brazilian legislation with its mandate of forest restoration on private lands is regarded as the main reforestation driver. Furthermore, the 2015 research by Rodrigues-Filho et al. suggests the same relationship. Their observations show how politics and institutions are important drivers for the future of Brazil's forests and that institutional weakness reflects trends in deforestation. When the institutional driver steering reforestation is changed, so will the outcomes of the forests.

This example shows that without proper policy measures, the future of forests can become unsure. It emphasises the power national governments hold over the future of forests. When there is a change in the political landscape, like increased institutional vulnerability after major elections, or a change in the political agenda (like the Bolsonaro administration) and their stance towards the natural world, significant impacts on the forests can follow relatively quickly (CAT, 2019a; Rodrigues-Filho et al., 2015). This means that if there is governance that provides incentives that benefit the socio-economic landscape for sustainable reforestation, for example, financial ones, there is also the possibility of recovery in a relatively short time frame, as Costa Rica's historical development showed. Governance therefore emerges as a critical component for the successful implementation of NDC mitigation goals and sustained reforestation, and thereby the attainment of the Paris Agreement. This critical position is also reflected by the arguments posed in scientific articles for the establishment of regulatory commitments that either take a leading role in economic policies or supersede them entirely to reach international climate goals (Brown et al., 2019). For Brazil specifically, improving the economics of forest restoration via, for example, productive forest restorative interventions or improved payment for ecosystem services could find great local support (Ghazoul & Schweizer, 2021). Furthermore, in order to reduce institutional vulnerability, a strengthening of governmental institutions is required (Rodrigues-Filho et al., 2015). This financial compensation is a step Costa Rica has already taken with its PES-system, which subsequently increased reforestation practises and correlated to all the reforestation that showed up in the dataset of this paper. Not only did their PES system have significant positive impacts on the forest area, it also provided socio-economic benefits. For example, between 1997 and 2019, more than 18,000 families benefited from the financial contributions (UNFCCC, 2019). A second successful financial incentive that Costa Rica offers is illustrated by their use of carbon compensation units. These examples suggest good governance is directly linked to land-owners and land managers' livelihoods.

In regards to financial incentives in Brazil, there have been several local water provision PES initiatives over the years by some states, municipalities, and sometimes public and private institutions, of which numerous have been terminated. Research suggests this was due to a lack of collective national scale efforts as well as poor communications, as it was often the case that PES systems in the given area were unknown to the main landowners (Prado et al., 2015). Research however also pointed out that there was great opportunity in these water PES programmes, stating the motivation for landholders was present. However, the barrier that prevents widespread success is pointed to as the absence of national PES legislation (Prado et al., 2015). The same holds true for small Brazilian PES initiatives relating to reforestation. Richards et al. showed with interview based research in 2020 that in such efforts, compensation has been too low, which limited the system's success, but again, motivation to partake would be there with sufficient financial incentive. Thus, if such PES schemes were developed for reforestation on a national scale, with sufficient compensation, this could potentially harbour great potential for reforestation practices in Brazil (Brown et al., 2019).

In this case, Costa Rica could serve as an example for future development in Brazil with regards to creating socio-economic incentives by means of policy measures that ensure sustainable reforestation takes place. By funding financial incentive systems through certification, ventures, and taxes, there is potential to overcome the financial gap needed to create sufficient incentives for landowners. National scale of a given system could further overcome the communication gap to inform the landowners. Thus, the tight connection between policy and socio-economics should be reflected in governance. The transition to restoring forests must ensure that inclusive, environmentally and socially sustainable economies are created, helping to combat poverty and inequality while preventing social exclusion or marginalisation (Ghazoul & Schweizer, 2021). Furthermore, in addition to creating incentives like this, deforestation ought to be halted if reforestation mitigation potential needs to surpass the losses to reach net gains and achieve sequestration to match the NDC and Paris Agreement goals.

Lastly, this paper shows that the NDCs in themselves also require change and input from multiple disciplines to set clearly defined requirements that reflect the multidisciplinary objectives of large-scale reforestation projects. The Brazil case showed an example of gaps between ambitions on the global podium and national capabilities as a result of political will, stressing the need for better monitoring practices (Rosenstock et al., 2019). These improvements can subsequently facilitate monitoring, progress tracking, and comparisons between countries. A clear overview of each country's progress can then better serve as the basis of a roadmap for the future and better inform collective goal setting on global podiums. In order to integrate the various terminologies used within country reports, a single language must be created and accepted by the various scientific communities involved (Nagendra & Southworth, 2009).

By viewing the reforestation efforts of both countries through the lens of separate disciplines and "breaking apart" the total narrative that is communicated to the wide public (including national policy makers) into small disciplinary perspectives, it became clear where policy and socio-economic limitations lie, and therefore where the biggest potential for growth is harboured if these policies are improved and incentives are provided. The findings of this paper match the narratives found in global literature regarding barriers and strategies in large scale reforestation (Brown et al., 2019; Nunes et al., 2020). This in itself is hopeful since it means that to overcome these challenges, we can build upon the experience of other countries that have followed a similar trend. In the same way, Brazil could learn from Costa Rica's historical developments. This highlights the importance of tight international collaboration because it is only possible to draw lessons from other cases similar to one's own if their developments have been strictly monitored on different disciplinary levels and subsequently communicated to others. The fact that data is multidisciplinary provides the contextual information necessary to draw comprehensive lessons from it. Therefore, if data is communicated through a well-developed and internationally consistent framework, nations can learn from each other. Thus, a plan like the Paris Agreement, which is global by nature, requires global cooperation for success.

DISCUSSION AND CONCLUSION

This paper provides insight into the reforestation goals as formulated in the 2015 NDCs of Costa Rica and Brazil, as well as the corresponding actions both countries have taken in the five year period after these plans were first submitted and their effects. The main findings show that Costa Rica has been very successful in its reforestation efforts, with the projection of exceeding its goal of 60% forest cover by 2030, which was set in the 2015 NDC, in its first five years. In contrast, Brazil shows an opposite trend in that it predicts that the goal of 12 million hectares of forest cover by 2030, as described in its NDCs, will not be achieved within its intended timeframe. Given the 672650 ha forest area lost in the first five years, interventions are necessary to halt and subsequently reverse this trend. Furthermore, the results of the case studies together with a body of literature indicate more widespread barriers and enabling conditions regarding reforestation efforts. The case studies seem to highlight a significant enabling factor, which mainly comes from policy developments that provide incentives, improve goal setting, and enhance monitoring for reforestation at the national level (Prado et al., 2015; Rosenstock et al., 2019).

The practical examples in the case studies suggest that the success of reforestation is dependent on the political landscape and policy making. Changes within this political landscape, similar to Brazil, seem to negatively reflect on reforestation success within a time span of a couple of years. Moreover, this dependence, which showed potential negative consequences in the case of lessened political will and funds for reforestation, could also have the potential to lead to large scale reforestation by land-owners and -managers in a short timeframe, as reflected by the historical developments in Costa Rica. A way to do this could be through introducing incentive-providing policies like the PES system in Costa Rica that encourage sustainable reforestation and also provide clear requirements and definitions on methods to prevent all deforested areas from being turned into plantation forests rather than restoring the natural forests (Ghazoul & Schweizer, 2021; Nagendra & Southworth, 2009). Furthermore, the Costa Rica case, where many landowners gained financial benefit, suggests socio-economic benefits could follow from such policies, especially if these systems are funded in ways that are sustainable for governments, such as, for example, through taxes on fossil fuels like in Costa Rica. More research into the relationship between financial incentives for reforestation and socio-economic benefit could provide further insight into the context and factors that steer the outcome of a given financial initiative.

Furthermore, literary analysis of current NDC reporting described how current reporting lacks transparency, consistency, and definitions or requirements, followed by stating the importance of global annual mandatory monitoring and communication using a uniform framework (Ellis & Moarif, 2015; Rosenstock et al., 2019). A description of how Costa Rica and Brazil incorporated reforestation as part of their NDCs and the subsequent framework analyses showed considerable data gaps in the FRA database, which complicated the deduction of trends from the framework and called for additional data sources to complete the analyses. This lack of data in the database is an example of how a lack of a complete framework and a lack of mandatory data reporting hinder comparisons between countries as well as progress tracking.

Within this paper, a brief overview is provided of the relevant historical trends in reforestation in both countries, showing that both countries have suffered losses in their forested areas, but Costa Rica became the first to halt the decline in forest area and reverse this historical trend by means of implementation of its PES-system. In contrast to the approach of the Brazilian government, which adopted a law mandating reforestation by rural landowners in attempts to halt this decline. What could be limiting in these historical overviews, however, is a potential lack of contextual information regarding other drivers and factors that have affected the outcome of the countries' historical and current efforts.

The same holds for the impacts of potential translation errors of NDCs and FRA reports resulting from a language barrier, which could cause misinterpretation of supplementary comments in the dataset that were provided in Spanish. Furthermore, as this paper only studied two Latin American countries, it could be the case that the drivers reflect this geographic focus. Further research could help in separating potential geographic bound drivers from global ones. Even though these limitations exist, the FRA data for these cases, accompanied by data from additional sources, were supported by scientific research that reflected the incentive-providing policy drivers and their socio-economic effects.

The innovative method of using the FRA framework as an analysis tool showed the added value of multidisciplinary progress tracking in regards to NDC reforestation goals. Furthermore, it highlighted the importance of uniform indicators and definitions. The FRA framework and database however also in certain aspects limits this paper's ability to provide an overview of all trends and progress over time. This approach showed several complications. First, there was a considerable lack of data in the FAO database (FAO, 2020b; FAO, 2020c) . Furthermore, the mandatory yearly data reporting as part of the requirements for the SDGs proved to be available for only a limited number of indicators. Based on the global report, the framework seemed to lend itself to a multidisciplinary analysis based on its balancing of biological, policy, and socio-economic objectives (FAO, 2020d). In the two case studies in this paper, however, there was little data available on policy and socio-economics, complicating the analysis of the NDCs from these perspectives. This lack of data could be an exception. Applying this analysis method to more countries could provide more insight into whether these cases were an exception, or that there is a trend in data lacking for certain disciplines on a wider scale. Furthermore, the indicators used in this framework were limited; for example, in biology, they were limited to only biophysical and spatial data. In regards to policy and socio-economics, the number of indicators was small. More research is needed to assess whether the current set of indicators in the FRA is sufficient to assess reforestation goals or if more indicators are needed when the framework is used to analyse reforestation efforts. Thus, overall, the FRA framework used in this paper did provide some insight into the course of action over the years but did not facilitate evaluation of these effects due to limited data availability.

In conclusion, the findings from this paper show how Costa Rica and Brazil both set ambitious reforestation goals in their 2015 NDC, yet adopted dissimilar political strategies in motivating reforestation efforts. While Costa Rica incentivizes by providing financial benefits, Brazil opts for legal mandates. The following analysis of both countries' actions in the five year period after the goals had been set showed how Costa Rica was likely to exceed its goals while Brazil's forests were declining and emissions were rising as a result of its changing political landscape. These impacts on reforestation following political changes highlight the policy potential to steer the outcomes of reforestation goals. Literature and the historical example of Costa Rica's success in this political approach with its national scale PES-system, showed how adequate financial incentives can motivate landholders to reforest. Furthermore, it showed how this can be a sustainable financial approach for governments by financing such schemes, for example, through fuel taxes or carbon credits. This case could potentially serve as an example in reversing the declining forest area trend in Brazil. Further research is recommended to determine if such an approach could be viable for other countries too. With improved and annual monitoring systems, the effects of incentives and goals can be measured and countries can draw lessons from each other's experiences, like Brazil potentially can from Costa Rica. In facilitating this, we move to more informed negotiators, achievable goals, effective measures, and better mitigation, and in doing so, mitigating the effects of climate change and protecting the natural systems on the planet we inhabit.

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APPENDICES

Appendix A: Disciplinary Frameworks

Table 13: Biology Framework

This table shows an overview of the biology framework used in this paper to analyse case studies. Adapted from FAO, 2020

Title	**Indicator**	**Unit**	**Reporting year**					
			2015	**2016**	**2017**	**2018**	**2019**	**Total change**
Forest extent and changes	1a Extent of forest and other wooded land	1000 ha						
	1b Forest characteristics: Planted forest	1000 ha						
	1c Annual forest expansion	1000 ha/year						
	1d Annual reforestation	1000 ha/year						
	1e Other land with tree cover	1000 ha						
Forest growing stock, biomass and carbon	2a Growing stock	m3/ha Million m3						
	2b Biomass stock	tonnes/ha						
	2c Carbon stock	tonnes/ha						
Forest disturb ances	3a Area affected by fire	1000ha						
	3b Degraded forest	Not applicable						

Table 14: Policy Framework

This table shows an overview of the biology framework used in this paper to analyse case studies. Adapted from FAO, 2020

Title	**Indicator**	**Unit**	**Reporting year**					
			2015	**2016**	**2017**	**2018**	**2019**	**Total change**
Forest designation and management objective	1a Designated management objective	1000ha						
	1b Forest area within legally established protected areas and forest area with long-term forest management plan	1000ha						
Forest ownership and management rights	2a Forest ownership: Public	1000ha						
	2b Forest ownership: Private	1000ha						
	2c Management rights of public forests	1000ha						
Forest policy and legislation	3a Policies, legislation and national platform for stakeholder participation in forest policy	Not applicable						
	3b Area of permanent forest estate	1000ha						

Table 15: Socio-economic Framework

This table shows an overview of the biology framework used in this paper to analyse case studies. Adapted from FAO, 2020

Title	**Indicator**	**Unit**	**Reporting year**					
			2015	**2016**	**2017**	**2018**	**2019**	**Total Change**
Employment, education and NWFP	1a Employment in forestry	1000 years full-time equivalents						
	1b Graduation of students in forest-related education	Number						
	1c Non wood forest products removals 2015	Value: 1000 local currency Quantity: local unit						

Appendix B: How my paper relates and contributes to the SDGs

As an aspiring changemaker, I argue it is important for each of us to reflect on the ways we contribute to a more sustainable world. Here follows a short reflection on how my own paper relates to the SDGs.

13: Climate action; Take urgent action to combat climate change and its impacts

I offer perspective on the existing situation, the objectives, and attempt to pinpoint the obstacles and favourable circumstances. This could contribute to better insight in current reforestation practices. Hopefully leading to improved and realistic reforestation initiatives across all disciplinary levels. To mitigate climate change and its effects, my paper will therefore assist in improving and increasing reforestation on a global scale, contributing to the 13th SDG.

15: Life on land; Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

Several significant co-benefits of reforestation relate to the 15th SDG. For instance, increasing reforestation improves soil conservation, hydrology, and biodiversity. improving terrestrial life as a result. These can be improved by better and more realistic goals and strategies.

17: Partnerships for the goals; strengthen the means of implementation and revitalise the global partnership for sustainable development

Although having a less direct relationship, I think my paper can benefit the 17th SDG. I offer a broad interdisciplinary viewpoint, which is unique because mono-disciplinary study is the typical methodology for this subject. It is possible to use the identified pitfalls and enabling circumstances as an advisory report for policymakers, economics, biologists, sociologists, and anybody else involved in reforestation. This may ultimately result in improved collaborations regarding reforestation on a larger scale both within and between the various disciplines.

Last but not least, I want to influence my readers' capacity for critical thought. I believe that learning this is a crucial ability for any policymaker. Partners must reflect critically on the data communicated to them to enable transparent and successful collaboration.