Supplementary Material (SM) for

“Policy sequencing to reduce tropical deforestation”

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**SM Methods**

***Compiling interventions***

We compiled the policy mix for reducing deforestation in our case studies by building on key policy references for each country: Costa Rica (Watson et al. 1998; de Camino et al. 2000; Brockett and Gottfried 2002; Navarro and Thiel 2007), Brazil (Nepstad et al. 2014), and Colombia (Furumo and Lambin 2020). We updated these lists of interventions with academic articles, government documents, reports from NGOs and intergovernmental organizations, and other grey literature including websites and news articles. Due to our interest in capturing the convergence of public policies, REDD+, and supply chain initiatives (SSC), we focused on more contemporary policy sequences surrounding the proliferation of multi-stakeholder interventions and how these are introduced into the existing domestic public policy mix. Given the large number of public land use and development policies put forth by governments, we narrowed our selection to those with an identifiable link to forest conservation. These included interventions in three general areas of policy: (1) explicit forest conservation, (2) forestry activities, and (3) sustainable agriculture. Using the key country references as a guide, we focused on the public policies that support or led to the development (i.e., antecedents) of these primary interventions. These included policies put forth by subnational governments where relevant.

Our interpretation of REDD+ extends beyond the formal sense of the official UN-REDD Programme. Following Nepstad et al. (2014) and Furumo and Lambin (2020), we use REDD+ as an umbrella term for a broad array of climate and development interventions that aim to reduce emissions through forest conservation or sustainable development. These include restoration projects classified under the “+” aspect of REDD. Note that domestic public policies related to REDD+ (e.g., national strategy) are classified under the REDD+ domain (Nepstad et al. 2013). We were unable to include all project-level REDD+ initiatives as many of these are developed in small communities by civil society groups and lack sufficient information to identify and characterize them. Furthermore, the inclusion of project-level activity would likely conflate the relative significance of REDD+ in the policy mix, particularly in large countries like Brazil and Colombia where at least 56 and 37 subnational and project-level REDD+ initiatives have been reported, respectively (Sills et al. 2014; http://www.reddprojectsdatabase.org/). We also do not include international treaties (e.g., UNFCCC, Convention on Biological Diversity) in the policy mix, but rather capture these global initiatives to the extent that they manifest in national policies.

The supply chain initiatives included in our database are not necessarily market-based strategies, but they all have in common the intervention of supply chains. They typically include multiple stakeholders and take the form of public-private partnerships or jurisdictional approaches. Early sustainability efforts along commodity supply chains largely focused on market-based eco-certifications, like sustainable timber (i.e., Forest Stewardship Council) and organic agriculture. In the early 2000s, the focus of voluntary sustainability standards (VSS) began shifting toward multi-stakeholder initiatives with commodity roundtables like the Roundtable on Sustainable Palm Oil. Major VSS have only recently developed explicit criteria banning forest clearing, and their impact on social and environmentally responsible commodity production has been mixed so far (DeFries et al. 2017; Oya et al. 2017).

Although we consider these VSS as part of the SSC domain, we did not include eco-certifications in our database as it was difficult to define a threshold or criteria for inclusion beyond presence/absence. Similar to the issues around classifying project-level REDD+ interventions, companies adopting certifications at the farm or plantation level are numerous and there is a lack of information to select a reliable indicator that systematically includes them (e.g., number of companies, share of market under certification). We also sought to avoid conflating the representation of supply chain initiatives in the policy mix due to the presence of multiple standards in each sector. At any rate, the three case studies share many of the same commodity sectors (e.g., timber, oil palm, coffee, banana, cocoa, sugar cane, beef) and their respective eco-certification standards (e.g., FSC, RSPO, Rainforest Alliance, Bird-Friendly Coffee, Fair Trade, IFOAM Organic, Global Roundtable on Sustainable Beef). For instance, significant portions of the oil palm sector in the three case studies are certified RSPO, but some VSS have only been adopted in one case study (e.g., Roundtable on Responsible Soy in Brazil). Beyond transnational examples of VSS, domestic roundtables, working groups, producer associations, and partnerships have also formed to support and coordinate the local definition and implementation of sustainability standards in commodity sectors.

Table S1. Categories of policy mechanisms and their instrument types. Adapted from Börner and Vosti (2013).

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| **Policy mechanism** | **Instrument type** | **Examples** |
| **Disincentive** | Area-based | Protected areas, territorial land use zoning |
| Ban | Forest conversion ban, criminalizing offenses |
| Standard | Permitting process, forestry protocols |
| Credit | Conditional credit, restrictions |
| Enforcement (legal) | Field raids, fines |
| Sanction | Litigation, carbon tax, moratoria |
| **Incentive** | Tax | Tax revenue allocated according to protected area coverage |
| Subsidy  | Grants, input provision |
| Bond | Redeemable bond certificate |
| Payment | Payments for environmental services (PES) |
| Credit | Credit conditional on reducing deforestation  |
| Market | Increased market access, demand for sustainable products |
| Offset | Emissions offset programs |
| **Enabling** | Institutional | Creation of environmental agencies, decentralization of authority, farmer technical extension services |
| Coordination | Inter-agency/sectoral coordination mechanisms, targets |
| Monitoring | National satellite-based forest monitoring systems |
| Finance | Nature/sustainable development funds |
| Pledge | Deforestation or emissions reductions |
| Partnership | Public-private, multi-stakeholder alliances |

***Classifying interventions***

 We classified each intervention along several criteria: (1) ***policy domain*** (i.e., domestic public policy, REDD+, SSC), (2) ***scale of intervention*** (global, national, subnational, sector), (3) ***instrument mechanism*** (i.e., disincentive, incentive, enabling), and (4) ***instrument type*** (e.g., area-based, market-based, financial). Following Börner and Vosti (2013), we considered the policy instrument(s) associated with each intervention and classified these according to how they attempt to influence an agent’s behavior and decision-making toward cutting or conserving forests (Table S1). *Disincentives* (‘sticks’) are coercive instruments that deter deforestation by increasing risk for the agent, typically resulting in reduced welfare. These include command-and-control policies with area-based (e.g., protected areas) or financial (e.g., tax, credit restriction) strategies. Disincentives may or may not be legally binding. *Incentives* (‘carrots’) provide positive reinforcement of good behavior (i.e., forest conservation) that increase agent welfare by offsetting opportunity costs. These may include fiscal (e.g., tax breaks), financial (e.g., subsidies, payments for environmental services), and other strategies (e.g., access to new markets, in-kind support). *Enabling* measures include a broad array of instruments or strategies that support and facilitate (dis)incentives. These include institutional (e.g., monitoring capacity, pledges), regulatory (e.g., land tenure reform), financial (e.g., nature funds), and coordination strategies (e.g., partnerships), among others. Under this mechanism, we distinguish between *institutional* instruments that make structural changes to governments (e.g., decentralization, creating new agencies) and *coordination* instruments that enhance processes (e.g., inter-agency protocols). We did not include more indirect enabling measures like environmental education campaigns or workshops. Domestic public policies and supply chain initiatives draw on all three instrument mechanisms whereas REDD+ initiatives involve incentives and/or enabling measures.

Broad national strategies, plans, or programs often contain multiple interventions that combine previously developed instruments and could thus be cross listed in several categories. We typically classified these as institutional or coordination enabling measures unless they featured a specific dominant strategy or instrument that was novel to previous interventions. Similarly, national laws introduced during legal reform can contain multiple instruments. When possible, we classified the constituent parts of these laws as separate interventions. For example, the 1996 Forest Law (7575) in Costa Rica banned forest conversion on private lands (i.e., disincentive) and introduced the national PES program (i.e., incentive). This law appears twice in our database listed as two separate interventions.

Given limitations in data collection, the policy mixes should be interpreted with caution. Firstly, we did not have information to reliably remove interventions that may have expired or been dismantled throughout the evolution of the policy mix in each country. This is particularly true for national plans or programs that may change under different political administrations. The policy mix at a given point in time is thus a snapshot of previous politically feasible strategies that may or may not still be in effect. For this reason, in the domestic public policy domain we focused on the legal and supportive framework for forest conservation and did not include the aspirational development plans put forth at the beginning of each new administration (these were only included to the extent that they became manifested as law or other policies). Secondly, without systematic evidence on the effectiveness of each policy in reducing deforestation, we were unable to weight the relative importance of each policy in the mix. A lack of systematic information on budget allocations and project funding also prevented us from weighting interventions along financial criteria. This means that the policy counts displayed in Figure 2 should not be interpreted as 1-to-1 in terms of scope and effectiveness—they instead offer a look at the comparative importance of different policy domains over time. Thirdly, we do not include antagonistic policies that directly contribute to deforestation. These include agricultural and development policies that favor economic priorities over environmental ones. Our aim was to uncover the macro trends of policy sequencing across the three broad actor domains and three general categories of instrument mechanisms. The evolution of national policy mixes to reduce deforestation is shaped by other factors beyond policy (e.g., market forces) that are also beyond the scope of this paper.

**SM Results**

***Country case studies***

In this section, we summarize the main national governance trends in the development of the policy mix to reduce deforestation. In each case study, we focused on the period of activity giving rise to the current mix of policies as identified in the key references for each country (see SM Methods above). These periods cover the proliferation of interventions to address deforestation in each country and are initiated by a significant government-led policy development (i.e., a national forest law in the case of Costa Rica and Brazil, and a zero-deforestation pledge in the case of Colombia). This time period varies across case studies and is indicated in parenthesis in the country sub-heading. Costa Rica, for instance, began pursuing policies to reduce deforestation much earlier than Brazil or Colombia. We also included any major, relevant forest policies introduced prior to these periods of aggressive deforestation control that had a notable influence on the current legal framework. For a detailed list and description of the policy mix in each country, refer to Tables S3 (Costa Rica), S4 (Brazil), and S5 (Colombia) in the worksheet (*“ZD\_sequencing\_SM\_tables.xls”*) included with these supplementary files.

*Costa Rica (1969-2019)*

Costa Rica is currently in the late stage of a national forest transition that has been largely driven by domestic public policies. Seventy-two percent of the national territory was forested in 1950 (Solórzano 1991). Subsidized loans for agriculture were subsequently introduced that led to rapid forest clearing for commodities, particularly coffee and sugar cane. Deforestation accelerated in the 1970s with the widespread expansion of cattle pastures for beef exports. To accommodate a growing population, government land redistribution and colonization programs also transferred the majority of the nation’s unoccupied forested lands from public to private ownership during this period (Watson et al. 1998). Forest clearing reached a rate of 50,000 hectares yr-1 reducing forest cover to just a quarter of the national territory by the mid-1980s (Kleinn et al. 2002; Navarro and Thiel 2007). The reversal of forest decline in Costa Rica is commonly attributed to the national *Payment for Environmental Services* (PES) program contained in the Forest Law (7575) of 1996, but earlier public policies and falling beef prices helped initiate this shift (Calvo et al. 2009). A first phase of policies focused on establishing area-based disincentives by expanding protected areas. A second phase introduced a series of incentives for reforestation and forest conservation. These sought to increase compliance of area-based strategies on public lands and increase forest cover on privately held lands. A third phase currently seeks to build on previous strategies by increasing forest cover in production landscapes through sustainable development. Initiatives for low-emissions agriculture are being advanced that are in line with national, cross-sectoral decarbonization targets.

In the 1970s, the government undertook significant expansion and consolidation of the nation’s protected areas. Less than 100,000 ha of land were protected in 1970, growing to nearly 600,000 ha by 1990 (de Camino et al. 2000). Protected area expansion and management was supported by international aid and debt-for-nature swap programs that helped develop innovative government finance mechanisms (Watson et al. 1998; Sheikh 2018). The initial 1969 Forest Law (4465) targeting forestry activities on private lands was consecutively reformed over this same period, reflecting the different strategies taken by the government to control deforestation. Reforms to the forest law in 1986 (Forest Law 7032) and 1990 (Forest Law 7174) enhanced regulations regarding forests and private plantations (de Camino et al. 2000). Permits and approval by licensed forestry professionals became required to cut trees on private properties, and government priority shifted from exploitative extraction of forest resources to forest management based on ecological and silvicultural considerations (Navarro and Thiel 2007). This was fueled by timber scarcity that caused the government to redirect subsidies from agriculture to the forestry sector, including tax exemptions in the 1970s and later transferrable bonds and credits in the 1980s that increased smallholder access. Forest conversion to agriculture became prohibited on lands with forestry aptitude. Reduced agricultural subsidies made smallholder farming less viable and led to farm abandonment in favor of tourism employment (Allen and Padget-Vásquez 2017).

Domestic policies and institutional reform during the 1990s sealed a reversal of deforestation trends. The revised Forest Law (7575) introduced in 1996 banned forest clearing on all private lands, mandated the conservation of riparian forests on productive lands, and prohibited the concession of public forested lands. This spurred intensification and allowed increased production of export-oriented crops (e.g., pineapple, banana) with minimal conversion of mature forest (Fagan et al. 2013; Jadin et al. 2016). Protected areas also doubled from less than 600,000 ha in 1990 to 1.3 million ha in 1999—roughly a quarter of the national territory—with significant land protected on private reserves (de Camino et al. 2000; Watson et al. 1998). Institutional restructuring sought to decentralize forest management and enhance public participation during this period (e.g., Organic Environmental Law 7554, 1995). To complement command-and-control policies, incentives were also reconfigured from supporting the forestry sector to forest conservation directly. Government subsidies for timber plantations were discontinued by 1995 (Brockett and Gottfried 2002), replaced with the system of payments for environmental services—water, carbon, biodiversity—that targeted standing natural forests. The national PES system has been considered widely successful and its rapid deployment benefited from the existing institutional capacity in place for compensating forest managers (Pagiola 2008). The main achievement of the PES system was increasing protection of forests on private lands. Together, the national system of protected areas and the PES program cover 70% of Costa Rica’s forests and 35% of its territory (MINAE 2017). More than half of Costa Rica is again forested today, though there is risk that regenerating forests undergo a relapse in clearing after several decades (Leighton-Reed et al. 2018).

By the early 2000s, success of the national PES system shifted government strategy from regulation to a market-based approach for controlling deforestation. Support for domestic policies was increasingly sought through transnational networks, and REDD+ initiatives signaled a third wave of policy actions aimed at reducing deforestation. The PES program had been supported by a mix of financing including a national fossil fuel tax and international development funds. Costa Rica pursued financing through REDD+ to expand coverage of the national PES scheme (Wallbott and Florian-Rivero 2018). Seeking to capitalize on carbon stored in protected areas, forests were further linked with the climate agenda. The main government priority of biodiversity conservation (particularly for eco-tourism) that underlined earlier policies gave way to the promotion of carbon-friendly sustainable production practices and a livelihoods focus that couples income generation with carbon sequestration (Wallbott and Rosendal 2018). In 2008, Costa Rica pledged national carbon neutrality by 2021, introduced a National Climate Change Strategy, and was selected for the Forest Carbon Partnership Facility in preparation of its national REDD+ strategy (Wallbott et al. 2019). In 2011, a voluntary national carbon market was established. A new national decarbonization plan for 2050 will be incorporated into Costa Rica’s nationally determined contribution (NDC) under the Paris agreement to be updated in 2020, focusing on emissions reductions in the transportation and agriculture sectors.

In addition to expanding support of the PES program with carbon payments under REDD+, the government is also seeking to advance forest restoration and sustainable agricultural systems through the REDD+ framework. Costa Rica committed to restoring one million hectares of degraded land under the Bonn Challenge. Sustainable practices in the coffee and livestock sectors is being advanced by Nationally Appropriate Mitigation Actions (NAMAs) under the UNFCCC framework and national strategy for low-carbon livestock production. Furthermore, an integrative agro-environmental strategy (*Agenda Agroambiental*) is being advanced by the government that seeks to integrate these isolated components of the sustainable agriculture and climate change agendas through a landscape approach (Navarro and Milla 2017; Wallbott et al. 2019). Taken together, recent policies in Costa Rica signal a shift from merely controlling deforestation to creating alternative, long-term models of sustainable production. Costa Rica’s pledge for carbon neutrality envisions an increase in forest cover to 60% of the national territory. The government does not plan to accomplish this by expanding protected areas, but rather by improving incentives and tools for expanding forest cover on private properties, particularly in agricultural landscapes.

Beyond commodity certification standards, supply chain initiatives have been conspicuously absent from zero-deforestation governance in Costa Rica. In addition to the NAMAs in the coffee and livestock sectors, public-private partnerships have been established in other commodity sectors but primarily focus on research and extension services, not market-based mechanisms. A recent supply chain initiative is the National Initiative for Sustainable Pineapple (*INSP*), a multi-stakeholder platform launched in 2011 with support from the UN Green Commodities program (https://www.pnp.cr/en). The initiative is a space for dialogue, coordination, and transparency among industry and government actors toward more sustainable management practices. A national monitoring platform for land use change in production landscapes—*MOCUPP*—is supporting the initiative and found that 5,000 hectares of forest was cleared for pineapple cultivation between 2000 and 2015 (http://www.mocupp.org/). MOCUPP is part of the Costa Rican national forest monitoring system, *SIMOCUTE*, being developed for REDD+ implementation. MOCUPP also tracks deforestation for oil palm, livestock, banana, and sugar cane commodity sectors. The platform links crop cover with a registry of properties thus allowing the government to monitor legal compliance with land use restrictions. It is further being used to promote zero-deforestation production of these commodities by providing open access farm-level traceability to commodity purchasers. Given the current policy focus on climate-smart agriculture and tools like MOCUPP, there is great potential for national-level zero-deforestation commitments to be formed and implemented in these commodity sectors.

*Brazilian Amazon (1996-2019)*

The Brazilian Amazon is the largest and best studied laboratory of how to establish a national climate strategy based on reducing emissions from deforestation. In 2004, around the height of forest clearing during the soy boom (~2.7 Mha year-1), the Agriculture, Forestry and Land Use (AFOLU) sector contributed nearly 80% of national carbon emissions; approximately half of this was from deforestation (Zarin et al. 2015). The current mix of deforestation control policies began under the Cardoso administration with the strengthening of the national Forest Code in 1996, a pledge to protect 10% of the nation’s forests in 1997, and the criminalization of deforestation in 1998. Aggressive deforestation control policies were greatly expanded under the subsequent Lula administration to disincentivize land clearing in the Brazilian Amazon. Integrated command-and-control measures were taken to expand protected areas on agricultural frontiers and crackdown on illegal activity with stricter law enforcement and fines (Soares-Filho et al. 2010; Nepstad et al. 2014). This was enabled by improved satellite-based forest monitoring (PRODES, DETER) and the development of a rural land registry (CAR) to enforce the national Forest Code (Hargrave and Kis-Katos 2013; Arima et al. 2014; Alix-Garcia et al. 2017). Enforcement capacity also enabled the government to restructure financial incentives to deter deforestation. Rural credit was restricted for a “blacklist” of municipalities that failed to address deforestation, elaborating on existing state-level green tax allocation programs (Assunçao et al. 2013; Nepstad et al. 2014). In Pará, a state-wide program extended penalties against poor performing municipalities by awarding credit for minimizing deforestation. These programs were designed to inspire collective action among landholders and re-align interests across multiple sectors at national, state, and municipal levels.

Parallel to public policy advancements, private sector initiatives were set up to reduce the demand for commodity-driven deforestation. In 2006, the Soy Moratorium was launched in the Brazilian Amazon, initiated by civil society campaigns that pressured powerful downstream actors into addressing deforestation in supply chains. The voluntary agreement offers a market exclusion policy by which traders and processors sanction the purchase of soy produced on farms that illegally deforested. The initial cutoff date was adjusted to match enforcement of the Forest Code (2008), depriving violators of market access and government financed credit opportunities (Gibbs et al. 2015). Similarly, a cattle moratorium was established in 2009 to pre-empt public regulatory action in the sector (Seymour and Busch 2016). Meatpackers in the region, representing 80% of the market, agreed to sanction cattle from blacklisted municipalities. The initial soy and cattle moratoria have been extended indefinitely and rely on the CAR and PRODES systems for continual implementation and monitoring. This form of private sector self-regulation can also be a corporate strategy deployed by firms pre-competitively across a sector to avoid activist pressure by doing more than the status quo, but less than what a government might demand in its absence (Malhotra et al. 2019).

The policy mix in the Brazilian Amazon has been considered largely successful for slowing deforestation. The period from 2004-2017 registered a 70% decline in forest loss while soy and beef production increased 130% and 70%, respectively. Sagging commodity prices and less profitable exports also contributed to the slowdown (Arima et al. 2014; Assunçao et al. 2015). Emboldened by progress, the government made an ambitious pledge to cut national emissions at the Copenhagen UNFCCC Conference of the Parties in 2009, including an 80% reduction in Amazon deforestation. This was an unprecedented commitment at the time and became enshrined in the national climate change mitigation plan, ushering in a wave of REDD+ initiatives that fused climate and zero-deforestation agendas (Seymour and Busch 2016). Chief among these was a billion-dollar investment from Norway to provide results-based payments for emissions reductions, supporting the Amazon Fund. Brazil’s pledge led to the National Climate Change law that established an important legal basis for pursuing zero-deforestation. Jurisdictional level commitments were also expanded through transnational networks like the Governors’ Climate and Forest Task Force (GCF), and autonomous state-level REDD+ strategies. Acre was an early leader in embracing REDD+ at the jurisdictional level, with Mato Grosso emerging as a leader in jurisdictional coordination as well. Subnational REDD+ approaches were bolstered by PES and conditional cash-transfer programs to support sustainable agriculture and development (e.g., Bolsa Verde, Bolsa Floresta). Further consolidation of the climate and forest agendas was later advanced through Brazil’s Nationally Determined Contribution under the Paris agreement which plans to end illegal deforestation in the Amazon by 2030 and restore 12 million hectares of native vegetation (Stabile et al. 2020).

Despite initial success, deforestation in the Brazilian Amazon has been steadily on the rise since 2012 and the nation’s forests face an uncertain future. A new Forest Code was passed that year and intended to increase compliance by reducing stringency but has been criticized as ineffective and allowing loopholes for agribusinesses to evade sanctions for deforestation (Acevedo et al. 2017; Carvalho et al. 2019). In response to the 2015 economic recession, public policies keeping deforestation in check were weakened to generate short-term economic gains. The move was made possible by the growing political strength of the rural agribusiness lobby (Crouzeilles et al. 2017). In 2017, Norway withdrew results-based payments to the Amazon Fund due to increased deforestation. Attempts to extend the soy and cattle moratoria to the Cerrado biome where deforestation leakage from the Amazon is occurring have been met with industry opposition. Under the Bolsonaro administration, environmental regulations and law enforcement have been scaled back even further and environmental institutions weakened (Carvalho et al. 2019; Ferrante and Fearnside 2019). Annual deforestation has increased 96% since Bolsonaro took office in January 2019 (Mongabay 2020). Soy farmers emboldened by Bolsonaro are pressuring to end the soy moratorium, while crushers and traders (i.e., ABIOVE) oppose dismantling it for fear of international boycott. The EU imports much of the soy and beef produced in Brazil. Given the accelerating deforestation associated with the production of these commodities, the EU is considering a boycott of Brazilian products by stalling ratification of the 2019 EU-Mercosur trade agreement (Rajão et al. 2020). Soy-related deforestation in the Brazilian Amazon is spatially concentrated on relatively few properties (Rajāo et al. 2020), thus compliant producers will likely support more stringent public regulations that level the playing field. Nonetheless, in response to the trade war between China and the United States, Chinese demand for Brazilian soy and beef is growing. As pressure for environmental restrictions from Chinese consumers is still limited, this new macroeconomic landscape may attenuate sustainable demand-side measures from Europe.

*Colombia (2009-2019)*

The national zero-deforestation agenda in Colombia has developed relatively recently compared to the other case studies. As a result, domestic public policies, REDD+, and supply chain initiatives have emerged near simultaneously and are highly integrated. Zero-deforestation initiatives in Colombia are rooted in efforts to reduce emissions and build peace. In 2016, a peace agreement was signed between the government of Colombia (GoC) and the FARC, the country’s largest armed rebel-group. Peace negotiations were accompanied by a subsequent surge in deforestation as actors sought to fill the power vacuum left by FARC demobilization in the countryside. In 2017, forest loss reached 220,000 hectares with 66% of this occurring in the Colombian Amazon (SMByC 2019). Land speculation has fueled much of the deforestation in the post-conflict period. In a process of land grabbing, cattle are commonly used to stake a claim on recently cleared lands until ownership can be acquired through a formal land titling process. Illicit crop cultivation (i.e., coca) has also been an important driver of deforestation that is opening up access in remote forest frontiers, including protected areas (Murillo-Sandoval et al. 2020). Yet with the signing of the peace deal there is a major opportunity for the government to expand its presence in rural areas affected by the armed conflict. Colombia is therefore at a crossroads in the post-conflict period: increasing peace and stability attract investments and development of previously inaccessible rural areas, but also increases the pressure on forests and biodiversity (Clerici et al. 2016; Baptiste et al. 2017).

In seeking rural economic stability, the government is pursuing a model of low-emissions development with a focus on sustainable agriculture and new supply chains supported by public-private partnerships (Furumo and Lambin 2020). Stopping deforestation is a central component of this national strategy. Prior to the peace accords when deforestation was relatively low, the GoC made an ambitious pledge at the UNFCCC 15th Conference of the Parties (COP) in 2009 to bring deforestation to zero in the Colombian Amazon by 2020. This pledge initiated the national zero-deforestation agenda. The pledge brought a wave of international cooperation to help Colombia meet this goal, largely REDD+ readiness funds and results-based payments. With the support of the REDD Early Movers program, the *Amazon Vision* program was established by the GoC to implement the zero-deforestation pledge. Amazon Vision serves as an umbrella project for large international REDD+ initiatives in the region sponsored by the UN Global Environmental Facility (GEF), Development Program (UNDP), and the World Bank. These focus on expanding and improving protected area management on the forest frontier. In 2018, Chiribiquete National Park was expanded from 28,000 to 43,000 km2, making it the world’s largest national park protecting a tropical forest. Amazon Vision also includes an agro-environmental pillar based on conservation agreements between the GoC and local associations of producers that aim to develop new supply chains in the region for non-timber forest products. These strategies are supported by enabling measures to expand technical assistance and green credit opportunities for farmers.

Colombia’s zero-deforestation pledge also brought substantial multilateral funding through a Joint Declaration of Intent among Norway, Germany, and the United Kingdom. These European nations pledged $300 million USD to Colombia in performance-based funding to make progress on reducing deforestation. Part of these funds were also policy-based and dedicated to the creation of national level zero gross deforestation agreements (ZDA) in four major commodity sectors—palm oil, beef, dairy, and cocoa. A fifth agreement is being developed in the timber sector. These ZDAs are unprecedented supply chain initiatives that aim for all production of these commodities in Colombia to be free of deforestation by 2020 (palm oil), 2025 (cocoa), or 2030 (beef and dairy). Deforestation-free commodities will be differentiated on the market by an eco-label to generate a price premium. These agreements include major producers—roughly 85% of national cocoa production and 35% of palm oil—as well as national processors and retailers (Furumo and Lambin 2020). Many participants of the ZDAs are also early adopters of certification standards like the Roundtable on Sustainable Palm Oil (RSPO), which can be used to demonstrate compliance with the national agreement in the oil palm sector. To implement the agreements, the government of Colombia has partnered with several transnational networks including the Tropical Forest Alliance (TFA), the Food and Land Use Coalition, and the Cocoa & Forests Initiative (World Cocoa Foundation). In 2019, the Joint Declaration of Intent was renewed until 2025, providing an additional $260 million USD of performance-based funding and $106 million USD of policy-based funding.

Jurisdictional REDD+ and supply chain initiatives are also playing an important role in scaling zero-deforestation initiatives in Colombia. The department of Caquetá—a large jurisdiction in the Colombian Amazon that contained 27% of the country’s total deforestation in 2017—became a signatory of the GCF and has become a champion of zero-deforestation efforts at the subnational level. A sustainable supply chain initiative in the department’s livestock sector—*Pacto Caquetá*—is scaling zero-deforestation efforts through value-added cheese production and new supply chains (Furumo and Lambin 2020). A multi-stakeholder jurisdictional approach has also been launched by the BioCarbon Fund in the eastern Orinoco region and is focused on sustainable agroindustry practices.

Institutionally, the REDD+ process accelerated important government reform in Colombia. A national climate change law was passed in 2018, focusing on two key mitigation strategies: REDD+ initiatives and a low carbon development strategy that requires key economic sectors to reduce emissions, including from deforestation. Colombia’s national REDD+ strategy also sets a bold target of zero gross deforestation by 2030. To help finance zero-deforestation initiatives, a national carbon tax was introduced in 2016, along with an offset program that allows the private sector to purchase credits exclusively from projects in Colombia.

Command-and-control measures have also been increased. The earliest forest policies in Colombia (Law 2, 1959) established the public forest domain but these regulations have never been properly enforced. In 2017, the GoC created the Intersectoral Commission on Controlling Deforestation (Decree 1257, 2017) to implement the REDD+ national strategy in the context of the peace accords. This coordinating body brings together development ministries with the Ministry of Defense and Attorney General’s office to address illegal activities contributing to deforestation. In 2018, the commission delineated the first ever national agricultural frontier, giving Colombia an important intersectoral land planning tool for forest protection. Closing the agricultural frontier was a major tenant of rural land reform under the peace agreement (Suárez et al. 2018). In 2019, the GoC stepped up law enforcement with *Operation Artemis*, increasing military raids on illegal deforestation. The national forest monitoring system (SMByC), developed under the REDD+ process, provides critical support through its system of early detection of deforestation events. In addition to developing forest reference levels for REDD+ and commitments under the Paris climate agreement, the SMByC also gives Colombia the capacity to monitor annual forest loss and is being utilized to track company compliance under the commodity zero-deforestation agreements. Annual rates of deforestation slowed in 2018 and reversed in 2019 for the first time since the signing of the peace deal. However, it is still not clear what effect zero-deforestation policies have had on recent deforestation trends.

**SM References**

Acevedo, A.A., Rajão, R., Costa, M.A., Stabile, M.C.C., Macedo, M.N., dos Reis, T.N.P., Alencar, A., Soares-Filho, B.S., Pacheco, R. (2017). Limits of Brazil’s Forest Code as a means to end illegal deforestation. *Proceedings of the National Academy of Sciences*, 114 (29), 7653-7658. https://doi.org/10.1073/pnas.1604768114.

Alix-Garcia, J., Rausch, L.L., L’Roe, J., Gibbs, H.K., Munger, J. (2017). Avoided deforestation linked to environmental registration of properties in the Brazilian Amazon. *Conservation Letters*, e12414. https://doi.org/10.1111/conl.12414.

Arima, E.Y., Barreto, P., Araújo, E., Soares-Filho, B. (2014). Public policies can reduce tropical deforestation: Lessons and challenges from Brazil. *Land Use Policy*, 41, 465-473. https://doi.org/10.1016/j.landusepol.2014.06.026.

Assunção, J., Gandour, C., Rocha, R., Rocha, R. (2013). Does credit affect deforestation? Evidence from a rural credit policy in the Brazilian Amazon. *Climate Policy Initiative*, Rio de Janeiro, Brazil. Accessed at: https://climatepolicyinitiative.org/wp-content/uploads/2013/01/Does-Credit-Affect-Deforestation-Evidence-from-a-Rural-Credit-Policy-in-the-Brazilian-Amazon-Technical-Paper-English.pdf.

Assunção, J., Gandour, C., Rocha, R. (2015). Deforestation slowdown in the Brazilian Amazon: Prices or policies? *Climate Policy Initiative*, Rio de Janeiro, Brazil. Accessed at: https://climatepolicyinitiative.org/wp-content/uploads/2012/03/Deforestation-Slowdown-in-the-Brazilian-Amazon-Prices-or-Policies-Technical-Paper.pdf.

Allen, K.E., Padgett-Vásquez, S. (2017). Forest cover, development, and sustainability in Costa Rica: Can one policy fit all? *Land Use Policy*, 67, 212-221. https://doi.org/10.1016/j.landusepol.2017.05.008.

Bauch, S., Sills, E., Estraviz-Rodriguez, L.C., McGinley, K., Cubbage, F. (2009). Forest policy reform in Brazil. *Journal of Forestry*, 107, 132-138. https://www.fs.fed.us/global/iitf/pubs/ja\_iitf\_2009\_bauch001.pdf.

Baptiste, B., Pinedo-Vasquez, M., Gutierrez-Velez, V.H., Andrade, G.I., Vieira, P., Estupiñán-Suárez, L.M., Londoño, M.C., Laurance, W., Lee, T.M., 2017. Greening peace in Colombia. Nat. Ecol. Evol. 1 (0102). https://doi.org/10.1038/s41559-017- 0102.

Börner J, Vosti S. (2013). Managing Tropical Forest Ecosystem Services: An Overview of Options. In: Muradian R. and Rival L., editors. Governing the Provision of Ecosystem Services. Springer; Netherlands: pp. 21–46.

Brockett, C.D., Gottfried, R.R., (2002). State policies and the preservation of forest cover: Lessons from contrasting public-policy regimes in Costa Rica. *Latin American Research Review*, 37(1): 7-40.

de Camino, R., Segura, O., Arias, G., Pérez, I., (2000). Costa Rica: Forest Strategy and the Evolution of Land Use. World Bank, Washington, D.C., USA.

Calvo, Alvarado, J., McLennan, B., Sánchez-Azofeifa, A., Garvin, T. (2009). Deforestation and forest restoration in Guanacaste, Costa Rica: Putting conservation policies in context. *Forest Ecology and Management,* 258: 931-940. doi:10.1016/j.foreco.2008.10.035

Carvalho, W.D., Mustin, K., Hilário, R.R., Vasconcelos, I.M., Eilers, V., Fearnside, P.M. (2019). Deforestation control in the Brazilian Amazon: A conservation struggle being lost as agreements and regulations are subverted and bypassed. *Perspectives in ecology and conservation*, 17 (3), 122-130. https://doi.org/10.1016/j.pecon.2019.06.002.

Clerici, N., Richardson, J.E., Escobedo, F.J., Posada, J.M., Linares, M., Sanchez, A., Vargas, J.F., 2016. Colombia: dealing in conservation. Science 254 (6309), 190.

Crouzeilles, R., Feltran-Barbieri, R., Ferreira, M.S., Strassburg, B.B.N. (2017). Hard times for the Brazilian environment. *Nature Ecology & Evolution*, 1, 1213. DOI: 10.1038/s41559-017-0303-7.

DeFries, R.S., Fanzo, J., Mondal, P., Remans, R., Wood, S.A., (2017). Is voluntary certification of tropical agricultural commodities achieving sustainability goals for smallscale producers? A review of the evidence. *Environmental Research Letters*, 12 (3), 033001.

Edwards, D.P., Socolar, J.B., Mills, S.C., Burivalova, Z., Koh, L.P., Wilcove, D.S. (2020). Conservation of tropical forests in the Anthropocene. *Current Biology*, 29, 1008-1020.

Fagan, M.E., DeFries, R.S., Sesnie, S.E., Arroyo, J.P., Walker, W., Soto, C., Chazdon, R.L., Sanchun, A. (2013). Land cover dynamics following a deforestation ban in northern Costa Rica. *Environmental Research Letters*, 8, 034017. http://dx.doi.org/10.1088/1748-9326/8/3/034017.

Matta, R. (2015). Towards effective national forest funds. Forestry Paper No. 174. *FAO*. Rome, Italy. Accessed at: http://www.fao.org/3/a-i4359e.pdf.

Ferrante, L., Fearnside, P.M. (2019). Brazil’s new president and ‘ruralists’ threaten Amazonia’s environment, traditional peoples and the global climate. *Environmental Conservation*, 46, 261-263. https://doi.org/10.1017/S0376892919000213.

Flagg, J.A. (2018) Carbon neutral by 2021: The past and present of Costa Rica’s unusual political tradition. *Sustainability*, 10, 296. doi:10.3390/su10020296.

Furumo, P.R., Lambin, E.F. (2020). Scaling up zero-deforestation initiatives through public-private partnerships: A look inside post-conflict Colombia. *Global Environmental Change*, 62, 102055.

Gibbs, H.K., Rausch, L., Munger, J., Schelly, I., Morton, D.C., Noojipady, P., Soares-Filho, B., Barreto, P., Micol, L., Walker, N.F. (2015). Brazil’s soy moratorium. *Science*, 347 (6220): 377-378. DOI: 10.1126/science.aaa0181.

Hargrave J., Kis-Katos K. (2013). Economic Causes of Deforestation in the Brazilian Amazon: A Panel Data Analysis for the 2000s. *Environmental and Resource Economics*, 54(4), 471–494. DOI 10.1007/s10640-012-9610-2.

Jadin, I., Meyfroidt, P., Lambin, E.F. (2016). International trade, and land use intensification and spatial reorganization explain Costa Rica’s forest transition. *Environmental Research Letters*, 11 (3), 049502. http://dx.doi.org/10.1088/1748-9326/11/3/035005.

Kleinn, C., Corrales, L., Morales, D. (2002). Forest area in Costa Rica: A comparative study of tropical forest cover estimates over time. *Environmental Monitoring and Assessment*, 73(1), 17-40. DOI: 10.1023/a:1012659129083.

Leighton-Reid, J., Fagan, M.E., Lucas, J., Slaughter, S., Zahawi, R.A. (2018). The ephemerality of secondary forests in southern Costa Rica. *Conservation Letters*, e12607.

Malhotra, N., Monin, B., Tomz, M. (2018). Does private regulation preempt public regulation? *American Political Science Review*, 113 (1), 19-37. doi:10.1017/S0003055418000679.

Mantilla-Cárdenas, L.M. (2015). La implementación del Plan Estratégico Nacional de Mercados Verdes en el departamento de Amazonas, Colombia, 2002-2011: Acierto o desacierto? Revista de Ingeniería, 48 (42), DOI: http://dx.doi.org/10.16924/riua.v0i42.844. Universidad de Los Andes, Bogotá.

Ministerio de Ambiente y Energía (MINAE) (2017). San José, Costa Rica.

Mongabay (2020). *Deforestation rate climbs higher as Amazon moves into the burning season*. https://news.mongabay.com/2020/07/deforestation-rate-climbs-higher-as-amazon-moves-into-the-burning-season/. July 10, 2020.

Murillo-Sandoval, Paulo J, Van Dexter, Kristina, Van Den Hoek, Jamon, Wrathall, David, Kennedy, Robert, et al., 2020. The end of gunpoint conservation: forest disturbance after the Colombian peace agreement. Environmental Research Letters 15, 3. https:// doi.org/10.1088/1748-9326/ab6ae3.

Navarro, G., Thiel, H. (2007). On the evolution of the Costa Rican Forestry Control System. Country case study #6. *Verifor*. Available at: https://www.odi.org/publications/3401-evolution-costa-rican-forestry-control-system.

Navarro, G. A., V. Milla. (2017). Costa Rica y su marco actual de políticas agroambientales hacia un modelo exitoso de restauración en paisajes rurales. Policy Brief. CATIE, Turrialba, Costa Rica. Accesed at: http://repositorio.bibliotecaorton.catie.ac.cr/bitstream/handle/11554/8821/Costa\_Rica\_y\_su\_marco\_actual\_de\_politicas.pdf?sequence=1&isAllowed=y

Nepstad, D., Irawan, S., Bezerra, T., (2013). More food, more forests, fewer emissions, better livelihoods: linking REDD+, sustainable supply chains and domestic policy in Brazil, Indonesia, and Colombia. *Carbon Management*. 4 (6), 639–658.

Nepstad, D., McGrath, D., Stickler, C., Alencar, A., Azevedo, A., Swette, B., Bezerra, T., DiGiano, M., Shimada, J., da Motta, R.S., (2014). Slowing Amazon deforestation through public policy and interventions in beef and soy supply chains. *Science* 344, 1118–1123.

Oya, C., Schaefer, F., Skalidou, D., McCosker, C., Langer, L., (2017). Effects of certification schemes for agricultural production on socio-economic outcomes in low-and middle- income countries. *Campbell Systematic Reviews* 13. https://doi.org/10.4073/csr.2017.3.

Pagiola, S. (2008). Payments for environmental services in Costa Rica. *Ecological Economics*, 65, 712-724. Doi:10.1016/j.ecolecon.2007.07.033.

Rajão, R., Soares-Filho, B., Nunes, F., Börner, J., Machado, L., Assis, D., Oliveira, A., Pinto, L., Ribeiro, V., Rausch, L., Gibbs, H., Figueira, D. (2020). The rotten apples of Brazil’s agribusiness. *Science*, 369, 6501: 246-248. DOI: 10.1126/science.aba6646.

Seymour, F., Busch, J., (2016). Why Forests? Why Now? The science, Economics and Politics of Tropical Forests and Climate Change. Center for Global Development, Washington D.C.

Sheikh, P.A. (2018). Debt-for-Nature initiatives and the Tropical Forest Conservation Act (TFCA): Status and implementation. Congressional Research Service report. https://fas.org/sgp/crs/misc/RL31286.pdf.

Sills, E. O., S. S. Atmadja, C. D. Sassi, A. E. Duchelle, D. L. Kweka, I. A. P. Resosudarmo, and W. D. Sunderlin (eds). (2014). REDD+ on the Ground: A Case Book of Subnational Initiatives across the Globe, Bogor, Indonesia: Center for International Forestry Research (CIFOR). Accessed online at: https://www2.cifor.org/redd-case-book.

Sistema de monitoreo de bosques y carbono SMByC, (2019). Instituto De Hidrología Meteorología y Estudios Ambientales (IDEAM). Bogotá, Colombia. http://smbyc. ideam.gov.co.

Solórzano, R., de Camino, R., Woodward, R., et al. (1991). Accounts overdue: Nature resource depreciation in Costa Rica. *World Resources Institute*, Washington, D.C.

Soares-Filho, B., Moutinho, P., Nepstad, D., Anderson, A., Rodrigues, H., and et al. (2010). Role of Brazilian Amazon protected areas in climate change mitigation. *Proceedings of the National Academy of Sciences*, 107 (24), 10821-10826. https://doi.org/10.1073/pnas.0913048107.

Stabile, M.C.C., Guimarães, A.L, Silva, D.S., Ribeiro, V., Macedo, M.N., Coe, M.T., Pinto, E., Moutinho, P., Alencar, A. (2020). Solving Brazil’s land use puzzle: Increasing production and slowing Amazon deforestation. Land Use Policy, 91, 104362. https://doi.org/10.1016/j.landusepol.2019.104362.

Stuart, M.D., Moura-Costa, P. (1998). Climate change mitigation by forestry: A review of international initiatives. Policy that works for forests and people, No. 8. *International Institute for Environment and Development*. Accessed at: https://pubs.iied.org/pdfs/7546IIED.pdf?.

Suarez, A., Árias-Arévalo, P.A., Martínez-Mera, E., 2018. Environmental sustainability in post-conflict countries: insights for rural Colombia. Environ., Develop. Sustain. 20 (3), 997–1015.

von Essen, M., and Lambin, E.F. (2020). Jurisdictional approaches to sustainable resource use. *Frontiers in Ecology and the Environment*, in press.

Wallbott, L., Florian-Rivero, E.M. (2018). Forests, rights and development in Costa Rica: A political ecology perspective on indigenous peoples’ engagement in REDD+. *Conflict, Security & Development*, 18 (6), 493-519. https://doi.org/10.1080/14678802.2018.1532643.

Wallbott, L., Rosendal, K.G. (2018). Safeguards, standards, and the science-policy interfaces of REDD+: Greening land use through forest-based mitigation in Costa Rica? The Journal of Environment & Development, 27(1), 99-125. https://doi.org/10.1177%2F1070496517751716.

Wallbott, L., G. Siciliano, and M. Lederer. 2019. Beyond PES and REDD+: Costa Rica on the way to climate-smart landscape management?. *Ecology and Society* 24(1):24.
https://doi.org/10.5751/ES-10476-240124

Watson, V., Cervantes, S., Castro, C., Mora, L., Solis, M., Porras, I.T., Comejo, B., (1998). Making space for better forestry. Policy that works for forests and people, No. 6. *International Institute for Environment and Development*. Accessed at: http://pubs.iied.org/pdfs/7530IIED.pdf.

Zarin, D.J., Harris, N.L., Baccini, A., Aksenov, D., Hansen, M.C., Azevedo-Ramos, C., and et al. (2016). Can carbon emissions from tropical deforestation drop by 50% in 5 years? *Global Change Biology*, 22 (4), 1336-1347. https://doi.org/10.1111/gcb.13153.