frontiers in Sustainable Food Systems

ORIGINAL RESEARCH
published: 17 June 2021
doi: 10.3389/fsufs.2021.635779

Elucidating Pathways and Discourses Linking Cocoa Cultivation to Deforestation, Reforestation, and Tree Cover Change in Nicaragua and Peru

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Specialty section:
This article was submitted to Agroecology and Ecosystem Services, a section of the journal Frontiers in Sustainable Food Systems

Received: 30 November 2020
Accepted: 19 May 2021
Published: 17 June 2021

Citation:
Orozco-Aguilar L, López-Sampson A, Leandro-Muñoz ME, Robiglio V, Reyes M, Bordeaux M, Sepúlveda N and Somarriba E (2021) Elucidating Pathways and Discourses Linking Cocoa Cultivation to Deforestation, Reforestation, and Tree Cover Change in Nicaragua and Peru. Front. Sustain. Food Syst. 5:635779. doi: 10.3389/fsufs.2021.635779

Cocoa cultivation is labeled as a driver of both deforestation and reforestation, yet the extent of the phenomena varies at farm and landscape level and as a response to national and local contexts. In this study, we documented the main pathways and contexts behind cocoa cultivation in two sites with different histories of cocoa cultivation. We combined official statistics, land-use trajectory, satellite imagery, and the Q-analysis to explore the discourses of country experts in Nicaragua and Peru. The Q-statements were based on an analysis of a set of legal, institutional, social, and technical guidelines that the cocoa cultivation/sector influences or is influenced by. Based on the responses of national experts to 31 statements we found four discourses linking cocoa cultivation and reforestation and deforestation in each country-case study. The enabling and limiting conditions driving tree cover change were a combination of landscape configuration, governance, management/commercialization models, and farmer's knowledge. Overall, between 60 and 64% of the variance was explained by four discourse factors in each country. In Nicaragua, the conditions associated with reforestation were the cocoa-agroforestry model promoted by local organizations/NGOs, the existence of incentives, degree of technical knowledge, access to safe market, and availability of improved genetic material. The circumstances associated with deforestation were the age of the farmers, fluctuation of cocoa beans prices, low productivity of cocoa plantations, and weak legal environmental frameworks. Whereas, in Peru, the main factors connecting cocoa cultivation to reforestation were access to market, degree of experimentation in cocoa, the economic weight of cocoa on family's income, certification processes, the existence of incentives, and the level of organization/association of cocoa farmers. The elements linking cocoa farming to deforestation were the influence of stakeholders in the cocoa value chain, weak legal environmental frameworks, fluctuation of cocoa prices, the existence of private investors, and insecure land tenure rights. This article demonstrated the utility of discourse analysis, through its application to two contrasting country case-studies, to elucidate the conditions that might minimize the deforestation footprint of cocoa cultivation and maximize its role as an agent for reforestation/restoration in the agricultural landscape of cocoa-growing areas in Latin America.

Keywords: cocoa farming, landscape, restoration, tree cover, reforestation, deforestation

INTRODUCTION

Cocoa covers around 10.2 million hectares worldwide. Up to 70% of the cocoa production is carried out by smallholders who manage 1–5 ha of shaded cocoa plots and produce about 4.47 million t annually [Fountain and Hütz-Adams, 2018; World Cocoa Foundation (WCF), 2019]. The remaining 30% of the global production comes from large-intensive (heavy agrochemical inputs and low to no-shade) plantations (Jezeer et al., 2017; Jagoret et al., 2018; Fountain and Huetz-Adams, 2020). Similar to other commodities/cash crops (i.e., palm oil, soybean, and ruminant livestock products), cocoa cultivation is a driver of both deforestation (mainly in Africa and Southeast Asia) and reforestation (mainly in Latin America) yet the extent of the phenomena varies at farm and landscape level and as a response to international, national, and local contexts (Kirby et al., 2006; Ruf, 2011; Tseng et al., 2013; Van Der Ven et al., 2018). Over the last five decades, the world's cocoa production has nearly doubled, yet cocoa yields from small farmers remained markedly lower in comparison to the yields attained under intensified cocoa plantations (Wade et al., 2010; Vaast and Somarriba, 2014; Notaro et al., 2020).

The upward trend of global production has been propelled by the extension of new cocoa fronts into forested and protected areas which resulted in the massive replacement of tropical forests in the major cocoa-growing areas. For example, on a global scale, between 1998 and 2008, 2–3 million ha of tropical forests were lost due to cocoa cultivation (Kroeger et al., 2017a). At the country level, for instance, in Indonesia in the same period (1998–2008) nearly 0.72 million ha of forest were cleared for cocoa production, equivalent to nine percent of the nation's total deforestation linked to agricultural commodities (8 million ha) (European Commission, 2013). The same trend has been reported for West Africa (loc.cit.). In South America, specifically in Peru, there has been a nearly five-fold increase in cocoa production between 1990 and 2013. Satellite images in 2012 showed a foreign company destroying ∼2,400 ha of forested area to grow cocoa, encroaching on the carbon-rich, biodiverse Peruvian Amazon rainforest (Dammert, 2017; Chirif, 2019, pp. 55, 61; Smith et al., 2020).

Nevertheless, cocoa cultivation is also an agent of reforestation and imply a stable way for tree planting and retention in agricultural lands (Jacobi et al., 2020). There is no exact data of the extent of cocoa grown under shade, however, Gockowski and Sonwa (2011) estimated that globally around 70% of cocoa is grown in agroforestry systems. Similarly, in Latin American, shaded cocoa accounts for 85% of the total cultivated area, so it might retain trees and prevent deforestation associated with cocoa production or other agricultural commodities (Somarriba et al., 2012; Schroth et al., 2016a; Pokorny et al., 2021). The establishment of cocoa agroforests is helping to restore about 68,000 ha of previously cleared pastureland (Schroth et al., 2016a). Experiences from Ecuador and Colombia also support this argument (Tscharntke et al., 2015; Middendorp et al., 2018). Moreover, shaded cocoa plays an important role in promoting biodiversity conservation, landscape connectivity, and restoration of abandoned/degraded land (Cassano et al., 2009; Deheuvels et al., 2012; Somarriba et al., 2013).

The transformation of forests into other agricultural land uses can be explained by a "forest transition curve" also referred to as the "tree cover transition curve" (Barbier et al., 2010; Dewi et al., 2017). The curve depicts how forests and tree cover decreases along a gradient of land-use change and agricultural intensification until a point is reached when tree cover is brought back into the agricultural land using various agroforestry or reforestation schemes including shaded cocoa plantations (Clough et al., 2011; Blaser et al., 2018). In any given landscape, cocoa plantations may be established following three different pathways: (1) pristine forests may be totally removed, and the land planted to various forms of open-sun agriculture or pastures, and these eventually can be converted into cocoa plantations, (2) forests may experience a direct transformation into different typologies of cocoa plantations (see Somarriba and Lachenaud, 2013 for a full description of the typologies). Finally, open-sun agricultural land may be converted to cocoa plantations (Somarriba and López Sampson, 2018). The transition pathways of cocoa cultivation are not linear neither in time nor in space and might respond differently to a wide range of stressors and drivers of social, political, and economic nature (Kroeger et al., 2017b; Ruf, 2018). For example, depending on the context and occurrence of the events cocoa can switch from the status of deforestation agent to one of a reforestation agent (Ruf and Zadi, 1988). Likewise, Rice and Greenberg (2000) pointed out that deforestation and cocoa cultivation cycles need to be carefully analyzed in light of the context where it is grown, for instance in alluvial soils of coastal areas of Indonesia cocoa, displaced agricultural areas, and in other cases, cocoa was planted in previously logged forested areas. More recently, a study found that cocoa farming has not been an important driver of deforestation in the main cocoa growing areas of Colombia and argued that interventions based on commodity value chain approach can support the peacebuilding process and achieve forest conservation/restoration commitments (Castro-Nunez et al., 2020).

The fundamental triggers behind the elimination of natural forests to plant cocoa are manifold. For example (Kroeger et al., 2017a) stated that the sustained trajectory of cocoa cultivation and deforestation is a direct response to rising demand for chocolate at global scale, decreasing production capacity from aging cocoa trees, lack of good agricultural practices, and shrinking suitable land area due to climate change (Läderach et al., 2013; Schroth et al., 2016c). These factors create further incentives to convert forests to farmlands for cocoa, which threatens remaining forested and protected areas (Ruf and Varlet, 2017). Listed enabling conditions linking cocoa farming with deforestation in Latin America are an absent/weak legal environmental framework, government-driven rural plans, and lack of market channels to profitably trade farms' products (Somarriba and López Sampson, 2018). Fortunately, market-driven initiatives such as the Cocoa and Forest initiative led by the private sector can help in tackling the challenges of increasing productivity on limited land while reducing pressure on forests and ecosystems, and enhancing climate change resilience (https://www.worldcocoafoundation.org/initiative/cocoa-forests-initiative/). Similar initiatives have been launched in South America (Colombia and Ecuador) where public-private partnerships have come together to work toward sustainable cocoa production [CF&P-Colombia (Iniciativa Cacao, Bosques & Paz Colombia). sf., 2018].

A large body of research confirmed that intensification to achieve higher cocoa yields often leads to a reduction in both shade levels and species richness (Wade et al., 2010; Soto-Pinto and Aguirre-Dávila, 2015; Tondoh et al., 2015; Schroth et al., 2016b). Some authors have suggested that shade levels are inversely proportional to attainable yields, yet the debate is still on-going. The common wisdom is that low shade or no-shade systems are winning the productivity battle. Moreover, crop intensification is the most important proximate driver in the transition from forest-like typologies to open-sun cocoa (Wade et al., 2010; Ruf, 2011). Crop intensification to boost cocoa yields is reducing or discarding shade tree cover altogether. However, the loss of livelihoods and ecosystem services associated with the loss of shade trees is rarely assessed (Tscharntke et al., 2011; Blaser et al., 2018). A recent study confirmed that on average, cocoa yields in agroforestry systems are 25% lower than in monocultures, but total system yields are more than 10 times higher, contributing to food security and diversified incomes. In addition, cocoa agroforestry stores 2.5 times more carbon and offer a more stable microclimate, such as lower mean temperature and buffer extremes temperatures (Niether et al., 2020).

The relationship between the expansion of cocoa into mature and secondary forests is well-documented for Africa and Indonesia and Brazil's Amazon forests but the extent of the phenomena remains poorly understood in other Latin American cocoa-producing countries (Alger and Caldas, 1994; Johns, 1999; Saatchi et al., 2001; Leiter and Harding, 2004; Kirby et al., 2006; Schroth et al., 2011). In this research, we combined satellite imagery, official statistics, land-use trajectory, and the Q-analysis to explore attitudes toward governance and the cocoa sector, and with this, shed light on pathways and discourses linking cocoa cultivation to deforestation, reforestation, and tree cover change in Nicaragua and Peru as study cases.

TABLE 1 | Number of farmers, cultivated area, production, average yield, imports, exports, certification labels and bean quality status of cocoa cultivation in Nicaragua and Peru.

Main features	**Countries**	
Production	**Nicaragua**	**Peru**
Total cocoa farmers (#)	11,000	90,000
Associated farmers (%)	40–50	35
Total cultivated area (ha)	10,907	145,169
Total national production (Mt)	6,600	121,825
Average yield (t/ha/year)	0.66	0.83
World ranking of producing countries	25th	8th
Exports/Imports		
Volume in Mt (% of exports vs. total imports)	1,872 (28%)	75,715 (81%)
Price (USD/Mt)	2,765	3,257
Value (×1000 USD)	5,179	148,357
Main markets	Guatemala (48%), Germany (28%), El Salvador (20%), USA (2%), Denmark (1%).	The Netherlands (31%), Belgium (18%), USA (9%) Canada (8%), Italy (6%).
Imports in t (% of imports vs. exports)	166 (9%)	5,465 (25%)
Quality status according to ICCO (2019)	85% fine and aroma	75% fine and aroma.
Certification/labels	Organic, Fair Trade, UTZ	Organic, Fair Trade, UTZ

Source: Wiegel et al. (2020).

METHODOLOGY

Description of Country Study Cases

We reviewed relevant technical reports, scientific publications, and official statistics to build a snapshot of the cocoa value chain in Nicaragua and Peru. The variables selected were cocoa cultivated area, total production, yields, export and import data, certifications, as well as the country's rank as a fine cocoa-producing country (**Table 1**). Nicaragua is ranked 25th and 1st as a producing country in the world and in Central America, respectively. Up to 85% of Nicaraguan cocoa is classified as fine (Martorell Mir, 2019). Small scale cocoa plantations are dominant countrywide, but a handful of medium-large scale plantations are in place as well. Cocoa is not a major crop in the agricultural matrix of Nicaragua but is closely linked to poverty alleviation, indigenous people, and the provision of environmental services within buffer zones (CATIE, 2013; Orozco Aguilar et al., 2015).

Peru is ranked 8th as a cocoa-producing country in the world and 3rd in South America. Like other neighboring cocoa-producing countries (i.e., Colombia and Bolivia) Peru has been subject to international aid to grow cocoa aimed at tackling the cultivation of illicit crops (Iturrios, 2016; Mithöfer et al., 2017a). Cocoa cultivation and trade in Peru have steadily increased during the last decade making the crop as an important commodity of economic importance for rural development (Minagri-Serfor, 2016; Pokorny et al., 2021). Up to 75% of cocoa produced in Peru is classified as a fine bean [Iniciativa Latinoamericana de cacao (ILCA), 2020]. In both countries, between 75 and 85% of cocoa is grown under the shade of trees with low-medium tree diversity (Vebrova et al., 2014; Somarriba and López Sampson, 2018).

Discourse Mapping and Experts' Views

In order to elucidate the pathways and discourses linking cocoa cultivation to deforestation, reforestation, and tree cover change in Nicaragua and Peru (national level), we divided the analysis into three phases: (1) Systematic literature review ranging from 2000 to 2020 using web-search engines (i.e., Scopus, Web of Science, and SciELO) where we consulted relevant articles and official reports to understand the economic/environmental/social role of cocoa cultivation in each selected country. Systematizing literature review is an important process to avoid the subjective and purposeful selection of articles (Pullin and Stewart, 2006). (2) Use of Q-method and media outlook to elucidate the arguments of in-country experts regarding cocoa cultivation and deforestation/reforestation processes. A total of fifty articles were selected, read, and analyzed to build the concourse around cocoa farming which was then validated by cocoa experts and (3) Spatio-temporal analysis using satellite imagery to track land-use changes in two localities within a given timeframe.

We used the Q-methodology to elucidate the discourse around the links between cocoa cultivation, deforestation, and reforestation in Nicaragua and Peru at the national level. Q-methodology uses both qualitatively and quantitative analyses to elucidate the discourses and opinions of a group of people on a certain issue (Ramlo, 2008). The Q methodology has gained prominence in natural resources management to explore attitudes toward governance, conservation, conflict resolution, and landscape approach (Nijnik et al., 2013; West et al., 2016; Langston et al., 2019). The basis of Q methodology is the Q-sort technique, which involves the rank-ordering of a set of statements from agree to disagree. The statements are based on concrete evidence taken from a systematic literature review or expert interviews. This set of statements are then the Q-sample (Brown, 1996). The Q-question of our research was: Which are the enabling/limiting conditions and drivers of cocoa cultivation that could influence the process of deforestation or reforestation in a certain zone or landscape? To apply the Q method, we used the findings of the systematic literature review to prepare the evidence (the concourse or knowledge around a particular topic) which helped in outlining the governance and processes surrounding the cocoa sector and its potential links to reforestation/deforestation processes in the two Latin America case countries selected. In our case, the concourse describing the relationship between cultivation and deforestation/reforestation consisted of 31 statements which became the Q-sample (statements) (**Supplementary Table 1**). The Q sample was grouped into six categories describing different processes/activities that the cocoa cultivation/sector influences or is influenced by: (1) Landscape configuration, (2) Production and commercialization model, (3) Knowledge/Skills/Training, (4) Governance, (5) Social capital/Social networks, and (6) Infrastructure. We targeted a group of experts in each country to elucidate (by ranking the Q-sample) the role of cocoa cultivation as a potential driver of land use and tree cover change at the national level.

TABLE 2 | Experts interviewed from different sectors across the value chain in Nicaragua and Peru.

Sector	Number of participants per country	
	Nicaragua	Peru
International NGOs	3	2
Government Institutions	1	2
Local NGOs	2	1
International Research Centers	1	1
National Research Center	na	1
Private landowners	3	2
Farmer's representative organizations	2	1
Independent consultants	2	2
Buyers/exporters	1	3
Industry	1	1
International Organization for Development	na	1
Total	16	17

Na: not available.

A total of 33 experts (16 from Nicaragua, and 17 from Peru) were tasked to sort the Q-statements (p-set or "sorters") using a scale from −3 (associated with deforestation), to +3 (associated with reforestation), 0 for neutral or no influence at all. The 33 participants represented different actors across the cocoa value chain (**Table 2**). All participants had an in-depth knowledge of the cocoa sector of their countries and could form a sound opinion of the Q-sample provided and were asked to sort. Additionally, all experts were questioned regarding the occurrence of any of the six cocoa typologies (**Figure 1**) as a proportion of total cultivated area for each country (national level) as well as to list and rank the causes or main reason why farmers or investors decide to plant cocoa as new crop or to remove forested areas to grow more cocoa within their intervention areas (local level).

The analysis of the Q-sorting involved correlation, factor analysis, and the calculation of factor scores (correlation coefficients) (Brown, 1996). The Q-sorts were analyzed using the Ken-Q-Analysis for the overall level of agreement and for recognizing distinguishable discourses through principal component analysis. To elucidate the most relevant factors only those with eigenvalues greater than one and explaining significant degrees of variance were retained and subjected to a varimax for rotation (Watts and Stenner, 2012). We only accepted factors upon which two or more participants placed statistically significant loadings (Brown, 1980).

Finally, a media outlook per country (national level) was collated to facilitate deliberations of experts linking cocoa cultivation to deforestation, reforestation, and tree cover

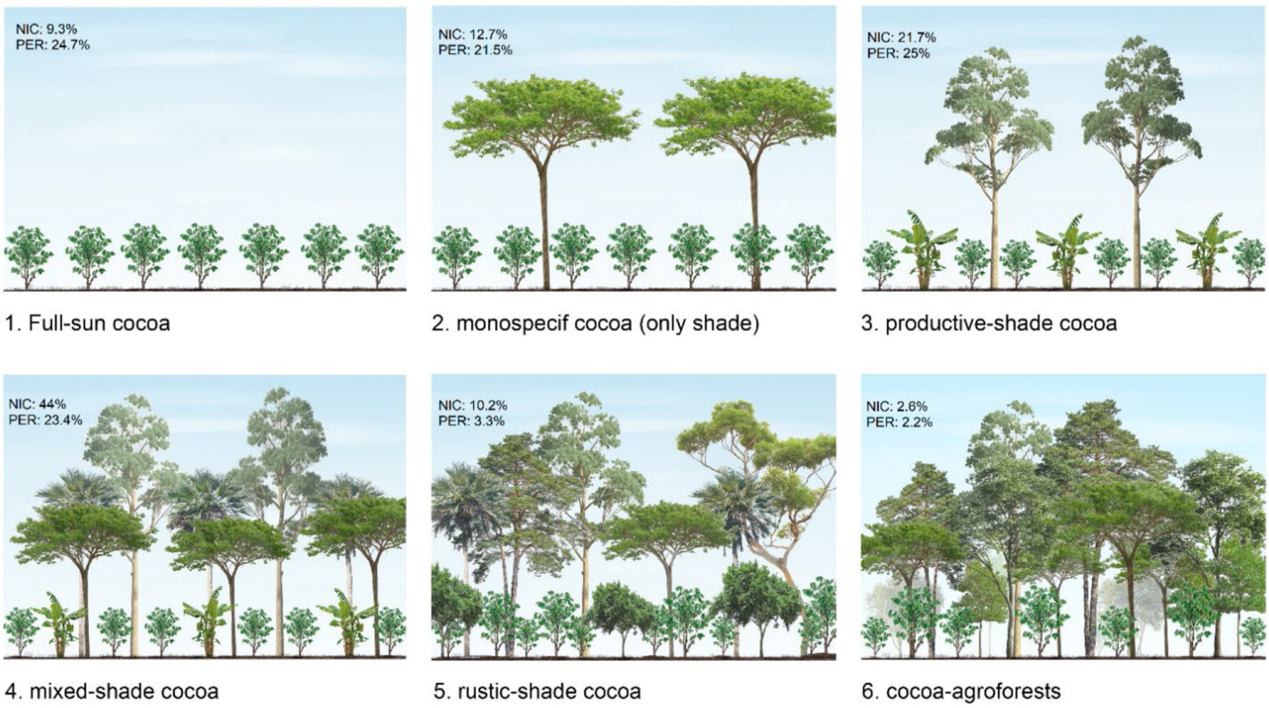

FIGURE 1 | Proportion of shaded cocoa typologies in Nicaragua (NIC) and Peru (PER) as expressed by in-country experts (see Somarriba and Lachenaud, 2013 for an in-depth description of the cocoa typologies).

change (Lockie et al., 2006; Takahashi, 2011; Swain, 2012). The media outlook was built using a web-based search engine to retrieve important news regarding cocoa cultivation and reforestation and deforestation processes during the period before and after 2010. We collated news/notes from major newspapers, national/regional forums, newsletters from research/development institutions and official publications from agricultural authorities in each country. The keywords used for our search were cocoa/cacao farming in combination with reforestation or restoration or deforestation or degradation. In order to consider a similar timeframe as the other methodological tools we used, the media outlook inputs were divided into two groups: deforestation/reforestation-related news before and after 2010. Links of retrieved news and media sources are provided as **Supplementary Material**.

Land-Use Change/Cocoa Cultivation Trajectory

Based on the literature review and to better answer the research question of this study, a timeline was created to document the milestones and contexts driving cocoa cultivation in one locality per country (Berdegué et al., 2007). A timeline is a venue to tell/construct a story documenting important events/life experiences around an issue (Kolar et al., 2015). In this research, we selected two different sites to create two timelines where the context and milestones surrounding cocoa development were annotated. The selected sites per country were Waslala located in the North-Caribbean Region in Nicaragua and Irazola, Ucayali in Peru. The municipality of Waslala was selected since it: (1) is the oldest and main cocoa production zone in Nicaragua since its inception as a traded commodity in the country (represents 20% of the country's cultivated area, produces ∼900 t of cocoa each year −35% of national production- and exports almost 500 t annually); (2) has been subjected to long-term investment in cocoa from both international cooperation and government aid (Martorell Mir, 2019); (3) well-documented experiences of development projects to re-create cocoa cultivation timeline (Navarro et al., 2013); and (4) is located within the buffer zone of one of the two biosphere national reserves of the country, Bosawas. The district of Irazola, Ucayali was selected for being: (1) one of the most important cocoa production zones in Peru with ∼11,000 ha; (2) one of the oldest deforestation frontiers in the Peruvian Amazon where migration has played a key role in shaping the smallholder land-use mosaic landscape since the 1940s (Robiglio and Reyes, 2016); (3) an implementing area of USAID-funded alternative development programs to replace illicit crops with cocoa and other crops; and (4) a learning laboratory for ICRAF with a long and active scientific and action working trajectory.

For the analysis of land-use/land cover change over time (regional/landscape level) we use satellite imagery from 2000 to 2015 available in the country for the selected sites. For Waslala land use/land cover maps were created based on a land cover/land-uses map of Nicaragua, 2015. Maps were prepared by the Nicaraguan Institute of Territorial Studies (INETER-https://www.ineter.gob.ni/) staff as a direct result of the regional program REDD-CCAD-GIZ, a joint effort between INAFOR, MAG, MARENA, and INETER. For the toponymies, the source of the information was INETER (1988 and 2006). MTI maps (2014) were used to create the road network, while the land cover/land-uses were obtained from processing and classifying 300 RapidEye satellite images taken between 2010 and 2012 with spatial reference system WGS84 UTM Zone 16 North and 6.5-m nominal ground resolution. Field verification was carried out by INETER in 2014 and 2015, obtaining an overall accuracy of 82.7% in 2000 and 86.9% in 2015. The map was classified into 17 land-cover/land-use categories based on the CORINE LAND COVER methodology (Ideam, 2008), the description of the mangroves of Nicaragua (INAFOR and FAO, 2008), the National Forest Inventory report (INAFOR and FAO, 2010), the Law No. 462 (Law of conservation, promotion, and sustainable development of the forestry sector, decree No. 73-2003 published in the Gazette of the Republic of Nicaragua No. 208 (2003)), and the norms, technical guidelines, and criteria for land-use planning adopted by INETER (2002).

Irazola land use/land cover maps were developed as part of the SECURED Landscapes project[1] implemented by World Agroforestry (ICRAF) in Peru during 2013 and 2015 (Reyes and Robiglio, 2016). We built a hierarchical land use/land cover legend using the Land Cover Classification System (LCCS v.2 software) developed by the Food and Agriculture Organization (FAO) (Di Gregorio, 2005). To identify land cover/land-use classes and collect ground-truth GPS points for image classification, we conducted 2-week fieldwork in Irazola during January 2014. We focused on understanding the different land-use trajectories by interviewing landholders during the field visits. This allowed us to refine the legend and identify 14 land cover/land-use classes. Cocoa could not be identified as an independent land-use class due to spatial resolution constraints, so cocoa falls within the shrub-fallow vegetation class. We followed Peru's Ministry of Environment technical protocol (Minam, 2014) and orthorectified two Landsat 5 TM and Landsat 8 OLI images of 30 m spatial resolution, path/row 007/066, dated September 2002 and 2015, spatial reference system WGS84 UTM Zone 18 South. Images were freely downloaded from Brazil's Instituto Nacional de Pesquisas Espaciais (INPE) and USGS Earth Explorer sites, respectively. We conducted a segment-based supervised classification using the Random Forest algorithm (Breiman, 2001) considering a minimum mapping unit of 0.5 ha. We assessed the classification accuracy with the Kappa index obtaining 0.76 and 0.85 for the year 2002 and 2015, respectively. Land cover/land use classes were grouped to facilitate comparison with the case from Nicaragua.

[1]Funded by NORAD, the project was implemented by Alternatives to Slash and Burn (ASB) and ICRAF in Cameroon, Indonesia, Vietnam, and Peru.

RESULTS

Discourses Linking Cocoa Cultivation to Reforestation, Deforestation, and Tree Cover Change

Experts' Views and Cocoa Cultivation Models in Nicaragua and Media Outlook

Most experts interviewed (90%) agreed that cocoa cultivation functions as a key agent of reforestation to enhance tree cover in the agricultural landscape. The cultivation models being promoted by development agencies, government bodies, and private industry were described as "agroforestry systems" where cocoa is grown in small plots (0.7–1.5 ha farm^{-1}) at 833 and 1,100 plants ha^{-1}, yet mean crop yields were low: 250–450 kg ha^{-1} year^{-1}. Cocoa was pruned twice a year (plant's height up to 4–6 m tall) and shade canopies were poorly designed and managed. From experts' view, cocoa shade canopies retained between 80 and 180 trees ha^{-1} and displayed three vertical strata (<10 m), medium (10–20 m), and high (>20 m tall) containing 50, 30, and 20% of total tree density, respectively. Most shade trees were planted, and some species are selected from the natural regeneration. In addition, mixed shaded cocoa is the dominant cocoa AF-typology occupying about 44% of total cultivated area countrywide followed by productive shade and cocoa with only shade species, although full sun cocoa is gaining momentum (**Figure 1**).

Based on the factor loading matrix (**Supplementary Table 2**) four factors were identified accounting for 64% of the total variance. These four factors represented four distinct discourses or arguments linking cocoa cultivation to reforestation and deforestation processes in cocoa-growing areas in Nicaragua. Each factor grouped the individual Q sorts significantly correlated with that factor. This arrangement reflects the knowledge and perception of the participants and does not necessarily support national strategies of the country or specific management regimes. Detailed descriptions of each factor are provided below.

- ***Factor 1 (aging farmers, low cocoa prices, low profitability and technical knowledge):*** The sorts of four participants were correlated with Factor 1 and included opinions from two farmer's organization representatives, one exporter, and one local NGO. In this factor, four variables and four distinguishing statements ($p < 0.05$) were associated with cocoa cultivation as an agent of deforestation. Age of cocoa farmers (S19), the profitability of cocoa plots (S11), and fluctuation of international cocoa prices (S24) were seen as enabling conditions potentially linked to deforestation. Nevertheless, in the same discourse, cocoa cultivation was related to reforestation when a certain degree of research/experimentation in cocoa exists in the country (knowledge, skills, and training domains). Moreover, interviewees believed that the cocoa-AF typologies promoted by development projects (S9), the existence of "payment for environmental services" initiatives (S21), and the level of organization/association of cocoa farmers (S26) could have a

TABLE 3 | Consensus statements* from the discourses of Nicaraguan interviewed cocoa experts.

No statement	Statement	*Q* value
2	In your country and/or in your intervention area, cocoa cultivation has a role as a reforestation agent.	2
9	The "AF-Cocoa typology" promoted by agroforestry projects in your country has a potential effect on the role that cocoa plays as an agent of reforestation.	3
18	The existence of "a national cocoa strategy/program/ plan" in your country has a potential effect on the role that the crop plays in the reforestation agenda.	0
20	The existence of "certification or another environmental labeling" in cocoa influence the view of the crop as an agent of reforestation in your country.	1
30	Having "access to centers of transformation" does not affect the role of the crop as an agent of reforestation.	0
31	The presence of "Financial Services" in the cocoa-producing areas can motivate the role of cocoa as an agent of reforestation	2

Those that do not distinguish between any pair of factors.

positive influence on the role of cocoa cultivation as an agent of reforestation as they were ranked high (Q-value = 3).

- ***Factor 2 (high-quality planting material, relative economic incomes, and access to markets)***. The sorts of five participants were correlated with Factor 2 and included the views from one government institution, one international NGO, one private landowner, and two independent consultants. Five variables and six distinguishing statements were the defining elements in this discourse. Here, cocoa cultivation was linked to reforestation when farmers grow improved cocoa germplasm (new clones/varieties) (S10). Interviewees expressed that cocoa cultivation is not related to the deforestation in their area of influence (S1). In addition, the existence of "payment for environmental services" initiatives (S21) and having access to safe markets (futures contracts or current market channels) (S28) were seen as neutral, that is, they do not have any association with cocoa cultivation as an agent of reforestation or deforestation. Nevertheless, the relative economic weight of cocoa on family's income portfolio (S6) and the profitability of shaded cocoa (S11) were mentioned as conditions that might influence the role of cocoa cultivation as a driver of deforestation.
- ***Factor 3 (Incomes from cocoa, low cocoa prices, and farmers' political incidence)***. The sorts of three participants were correlated with Factor 3 and included the opinions from one private landowner, one representative of research/academy, and one local NGO. Three variables and five statements were the distinguishing elements in this group. In this discourse, cocoa cultivation was connected to the deforestation. The main reasons listed were the economic weight of the crop on family's income portfolio (S6), and similar to Factor 1, the fluctuation of international cocoa prices (S24) and the political level of influence exercised by cocoa groups/value chain stakeholders (S23). One on hand, the lack of secure land rights (S3) is seen as negative and might limit the role of cocoa as driver of reforestation. On the other hand, low productivity (<400 kg ha^{-1}) of cocoa plantations (S8) is seen as neutral, so there is no significant influence on reforestation/deforestation processes.
- ***Factor 4 (Payment for environmental services, land tenure, and minimum area under cocoa)***. The sorts of three participants were correlated with Factor 4 and included the thoughts from two international NGOs and one industry actor. Three variables and four distinguishing statements were the elements that defined this discourse. In this group, cocoa cultivation supporting reforestation was linked to the existence of incentives such as "payment for environmental services" initiatives (S21) and the availability and planting of superior genetic material (clones/varieties) by farmers/growers (S10). Unlike the discourse of group 3, the "lack of secure land rights" (S3) does not have any influence on reforestation or deforestation processes linked to cocoa cultivation. The minimum size of cocoa cultivated area (S7) was mentioned as an enabling condition to deforestation processes. Small cocoa plantations with unproductive trees could lead to deforestation to grow more cocoa and meet market demand.

Consensus: *Six* consensus statements were determined based on the Q analysis. Four out of six statements were positively linked to reforestation and two statements were ranked as neutral (**Table 3**). All four discourses agreed that cocoa cultivation can be considered as a pathway for reforestation and to enhance tree cover. Yet, participants agreed that the potential role of cocoa as an agent of reforestation is influenced by the type and extent of the AF-cocoa typology being promoted across the country. The more diverse and complex the AF-cocoa typology the greater the role of tree cover change. Interviewees argued that the existence of certification/sustainable labeling for cocoa, as well as the availability of financial services to cocoa farmers, might maximize the positive links between cocoa cultivation and reforestation, however the latter condition (access to financial services) is not a mainstream condition. Regarding sectoral strategic planning and access to transformation centers (i.e., post-harvesting infrastructure), experts do not see them as having any effect on the role of cocoa cultivation as a driver of either reforestation or deforestation.

At country level, the media outlook from both international and national lenses was also in line with the discourses given by interviewed experts (**Figure 2**). Before 2010, the media outlook linked deforestation process to other drivers mainly illegal mining, logging, fires, and colonization movements registered into protected areas. After 2010, a few studies (mostly from national media) connected cocoa cultivation with deforestation events. From 2010 and onwards, the links between cocoa cultivation and reforestation were widely documented by the media, especially from international research institutions. The message was clear: cocoa is acting as a key agent of reforestation countrywide since is being planted on previously deforested land. In addition, most sustainability report from private companies

FIGURE 2 | Nicaragua's media outlook (before and after 2010) linking cocoa cultivation to reforestation and deforestation.

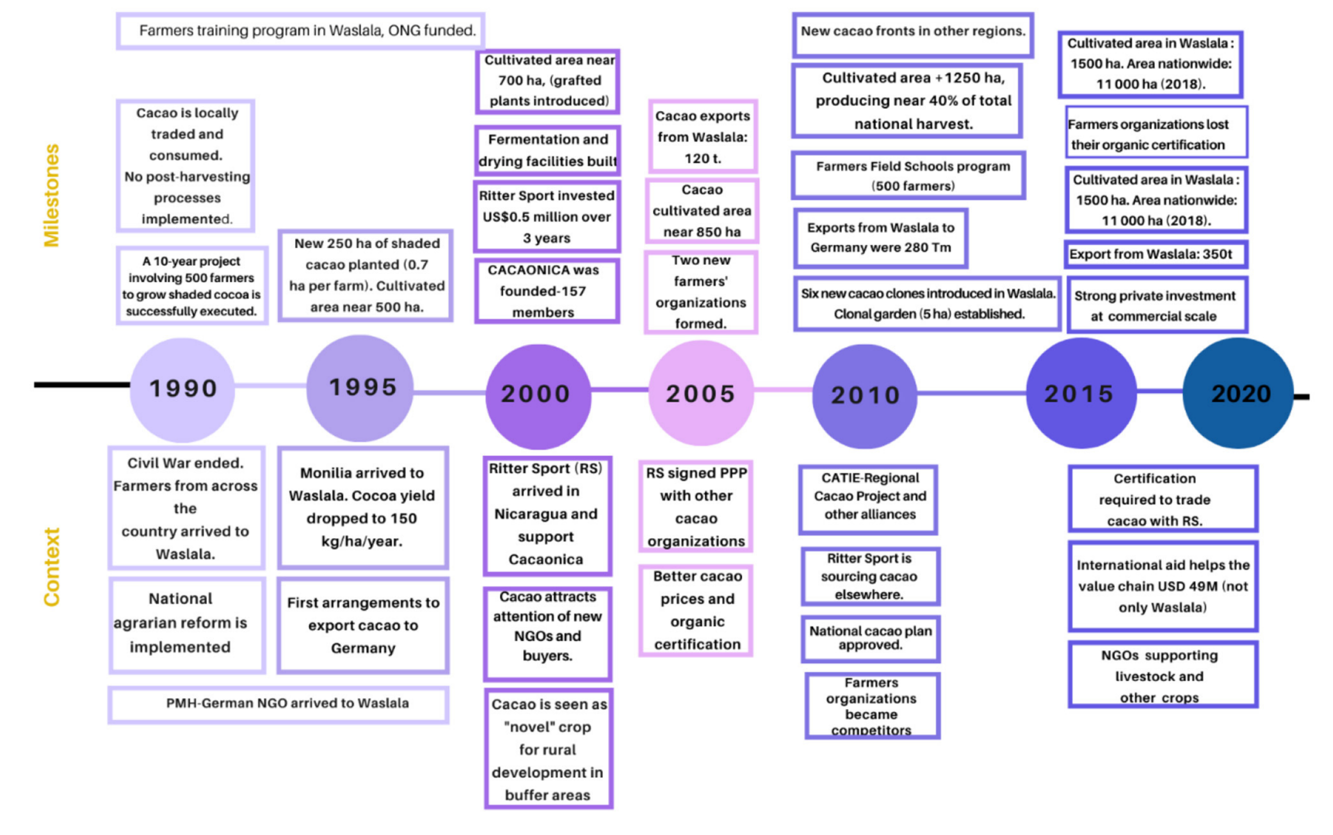

FIGURE 3 | Timeline (milestones and context) of cocoa cultivation in Waslala, Nicaragua.

highlighted the "environmental value" of growing shaded cocoa plantations and emphasized their efforts to contribute to the country's reforestation/restoration targets. The media outlook has played a crucial part in attracting government's attention which has now included shaded cocoa- in the national development plan as a promising crop for rural Nicaragua.

Land-Use Change/Cocoa Trajectory: Insights From the Municipality of Waslala, Nicaragua

The trend of labeling cocoa as key crop for reforestation that was identified in the media outlook can also be supported by analyzing more in depth the trajectory of cocoa cultivation (**Figure 3**). For example, in Nicaragua, specifically in Waslala, cocoa farming followed a cycle of the war-peace process, national land reform, and modest support from international NGOs in the 1980s, this context brought about opportunities for the establishment of the small cocoa plantations (about 250 ha, mainly seed-based cocoa), fostered market insertion (besides coffee, cocoa was the first-international market-tree- based crop), and enriched social networking and capacity building. In the 90s, 250 ha of cocoa were established and in the 2000s the first cocoa-based organization (cooperative). was founded. Cocoa cultivation and trading in Waslala experienced a period of bonanza between 2000 and 2010 (500 ha of new cocoa plantations and 120 Mt of beans were exported) when several key actors brought incentives and special conditions, such as access to improved planting material, systematic on-field training, and access to good prices and better links to markets, placing cocoa as a profitable crop suitable for supporting small farmers' livelihoods.

Between 2010 and 2014, new working relationships were fostered, for example, private-public partnerships between cocoa-farmer organizations and exporters/buyers were established, organic certification was set as a requirement to enter/secure international markets leading to sustained cocoa exports from the area. However, this "cocoa boom" did not motivate farmers to significantly expand the area under cocoa. From 2014 and onwards, development projects moved away from Waslala to new areas and triggered new cacao fronts elsewhere. The main cocoa buyer also started formalizing commercial relationships with new farmers' organizations, lowered the quota of cocoa traded and reduced additional benefits (financial support for certification, training programs, and agricultural inputs) given to Waslala farmers. Middlemen played a key role in sustaining the trading of cocoa from Waslala but at lower prices which, in turn, affected bean quality standards achieved by organized farmers so far. Lower incomes discouraged farmers to either plant more cocoa on their farm or give proper crop management. From 2015 and onwards, efforts were made to improve the governance of the cocoa sector (national cocoa plan and cocoa board in place), and large-scale private investments were now part of the national cocoa landscape. Under this new context, the reported stall in cocoa expansion was probably due to the shifting focus

TABLE 4 | Land-use change (ha) between 2000 and 2015 in the municipality of Waslala, Nicaragua.

Land-use type	2000	2015	Change	% of change	% relative to total area
Open broadleaf forest	31,532	21,544	−9,988	−32%	−7%
Closed broadleaf forest	10,284	15,141	4,857	47%	4%
Open pine forest	4	7	3	66%	0%
Closed pine forest	70	51	−20	−28%	0%
Scrubland	13,244	24,010	10,766	81%	8%
Bushy vegetation	19,296	2,067	−17,229	−89%	−13%
Herbaceous vegetation	57	0	−57	−100%	0%
Perennial crops	872	989	117	13%	1%
Annual crops	1,348	2,289	941	70%	1%
Pasture	55,711	66,382	10,672	19%	8%
Soil without vegetation	72	0	−72	−100%	0%
Urban area	51	54	2	5%	0%
Water course	788	796	8	1%	0%
Total	133,300	133,300			

of international/governmental aid in Waslala shifted to include other cash crops and other areas across the country.

Analysis of the images of land use/land cover of Waslala municipality, in the 2000s, shows most of the land was dedicated to pastures (42%), followed by open or degraded forest (31%) and only 1% was covered by perennial crops (i.e., coffee and cocoa). Fifteen years later, remarkable land-use changes occurred (**Table 4**, **Supplementary Figure 1**). For example, pastureland increased by 19% and now covers half of the territory, open broadleaf forests were significantly reduced (32%), shrubland increased 81% and bushy vegetation decreased by 89%. Between 2000 and 2015 about 120 ha of cocoa were established (a modest increase of 13%) and the crop now covered 1% of the agricultural landscape. The major drivers of tree cover declined in the Waslala landscape were livestock, small-scale agriculture, and timber harvest from legal and illegal sources. The current extent of cocoa cultivation in Waslala landscape is too small to shift this trend.

Experts' Views and Cocoa Cultivation Models in Peru and the Media Outlook

Experts interviewed from Peru stated mixed opinions regarding the role of cocoa cultivation as an agent of reforestation or deforestation. Almost half of them (45%) labeled cocoa cultivation as a driver of deforestation within their area of intervention. The remaining 55% granted that cocoa farming plays a crucial role as agent of reforestation to enhance tree cover in any given landscape. The cultivation models being promoted by development agencies, government bodies, and private industry were categorized as "various types of shading systems" where cocoa is grown in plots ranging from 2.5 to 3.5 ha farm^{-1} with 1,100 to 1,250 plants ha^{-1}, better agronomic management (fertilization-chemical or organic-) are given so farmers get higher yields (700–1,000 kg ha^{-1} year^{-1}) as compared to reported yields in Nicaragua. Cocoa trees were pruned twice a year and reached about 2.5–3.5 m in height. Experts indicated that shade tree density ranges between 60 and 120 individuals ha^{-1} and shade canopies displayed two vertical strata, low (<10 m) and medium (10–20 m), containing 60 and 40% of total tree density, respectively. Timber trees such as capirona (*Calycophyllum spruceanum*), bolaina (*Guazuma crinita*), and tornillo (*Cedrelinga cateniformis*) were among the species frequently managed in the cocoa canopy and they were planted in linear arrangements combined with *Musa* spp., and leguminous species as temporal shade. Based on expert's views cocoa agroforestry typologies were evenly managed across the country (**Figure 1**) however, productive shade, mixed shaded cocoa and full sun were the dominant cultivation models. Rustic cocoa and agroforests occurred at lower proportions.

According to the factor loading matrix (**Supplementary Table 3**), four factors were identified, accounting for 61% of the total variance. These four factors represented four discourses linking cocoa cultivation and reforestation/deforestation processes in cocoa-growing areas in Peru. Each factor grouped the individual Q sorts significantly correlated with that factor. This arrangement reflects the knowledge and perception of the participants and does not necessarily support national strategies of the country or specific management regimes.

- ***Factor 1 (Payment for environmental services, certification and shaded cocoa typologies):*** The sorts of nine participants were correlated with Factor 1 and included two governments' representatives, one exporter, one farmer's organization representative, one private landowner, one local NGO, one international NGO, one international research center, and one independent consultant. In this discourse group, nine variables and 10 distinguishing statements were the defining elements. Of this set of statements, five associated cocoa cultivation as agent of reforestation, three statements linked cocoa farming to deforestation processes and two were ranked as neutral. In this discourse group, cocoa cultivation is directly mentioned as a reforestation agent (S2). The existence of payment for environmental services initiatives (S21), certification/sustainable labeling (S20), on-farm diversification (S12), and the cocoa-AF typologies promoted by projects (S9) were conditions linked to reforestation. Whereas, the enabling circumstances associated with deforestation were the absence or the existence of weak legal frameworks/policies (S22), the lack of secure land rights (S3), and the existence of private investors (S25).

- ***Factor 2 (Aging cocoa plants, certification, price fluctuation, and national strategy/plans):*** The sorts of two participants were correlated with Factor 2 and included one private landowner and one international NGO. In this discourse group, two variables and seven distinguishing statements were the defining elements. Overall, cocoa cultivation was linked to reforestation (S1), and the enabling conditions listed were the age/productive status of the cocoa plantations (S13) and the existence of certification or environmental labeling in cocoa (S20). However, in this discourse, some elements can influence the role of cocoa as an agent of deforestation, and they were the predominant agrarian extension model of cocoa projects (S18), the prevailing paperwork and costs to legally cut/harvest timber trees (S4), the existence of a national strategy/plan/program for cocoa (S18) and the fluctuation of cocoa prices in the international market (S24).
- ***Factor 3 (Cocoa profitability, road development, and level of political leverage by farmers):*** The sorts of two participants were correlated with Factor 3 and included one national research institute and one international for development organization. In this discourse group, two variables and five distinguishing statements were the defining elements. Cocoa cultivation can contribute to reforestation if cocoa farms are close to roads (S29), cocoa profitability is safeguarded and sound commercial links to trade AF-agroforestry products exist (S14). While the enabling conditions linking cocoa farming to deforestation processes were the political power/leverage exercised by the cocoa sector or stakeholders (S23) and the existence of private investors (S25).
- ***Factor 4 (Cocoa price, the political power of investors, land value, and weak legal framework):*** The sorts of two participants were correlated with Factor 4 and included one exporter and one industry player. In this discourse group, two variables and eight distinguishing statements were the defining elements. The elements/conditions connecting cocoa cultivation to deforestation were the political power/leverage exercised by the cocoa sector or stakeholders (S23), price fluctuation of cocoa in the international market (S24), and the level of on-farm diversification (S12). While the conditions linking cocoa farming to reforestation were better cocoa prices paid at farm level (S11), the minimum size of area cultivated (S7), and genetic composition (clones/varieties) of the cocoa grown on the farms (S10). The existence of financial incentives, i.e., payment for environmental services (S21), the value of the land (S5) and the absence/weakness of legal frameworks/policies (S22) might function as enabling conditions to trigger deforestation.

Consensus: Overall, participants agreed on two statements (**Table 5**) that were positively linked to reforestation processes. The level of research/experimentation on cocoa (knowledge, skills, and training domains) and the presence of financial services in the cocoa-producing areas might drive cocoa cultivation as a potential pathway to enhance tree cover at landscape level. The cocoa-AF- typology being implemented by private actors on medium-large-scale farms might also have a role to play.

TABLE 5 | Consensus statements* from the discourses of Peruvian interviewed cocoa experts.

No statement	Statement	Q-value
16	The level of research/experimentation in cocoa in your country/zone has any effect on the role that the crop plays as an agent of deforestation/reforestation	1
31	The presence of "Financial Services" in the cocoa-producing areas can motivate the role of cocoa as an agent of deforestation/reforestation"	1

*Those that do not distinguish between any pair of factors.

The media outlook in Peru was also in line with mixed discourses given by interviewed experts. A blend of media messages can be seen depending on the time, source and the extent of the issue being reported. For instance, at the beginning of the 90's the media (national and international) was focused on the growing drug trade and terrorism which dominated most rural areas in Peru, in addition, the media also showed that during the 80's and 90's, deforestation in the Peruvian amazon was led by agricultural intensification specially for coffee and coca (*Erythroxylum coca*). After the drug crisis (from 2010 and onwards), international media strongly linked cocoa cultivation and deforestation and tree cover change, especially when private investors were involved and cocoa farming was encroaching protected areas such as the Amazon rain forest (**Figure 4**). At this time, the Peruvian government acted on well-known cocoa cultivation-deforestation events led by private investors and by channeling funds to implement regional plans to grow cocoa and tackle the farming of illicit crops while restoring previously deforested areas. Another segment of media, particularly that of regional research institutions, industry players, chocolate companies, and government agencies, was trying to balance the message and to reverse the public view of cocoa as an agent of deforestation by highlighting private and public partnerships and documenting success stories on sustainable cocoa cultivation from several locations across the country. Currently, national media assigned a crucial role to cocoa cultivation as an alternative crop to lower deforestation, enhance tree cover, and protect the remaining forests while supporting farmers' incomes from legal sources.

Land-Use Change/Cocoa Trajectory in Peru: Insights From Irazola, Ucayali

The trend of cocoa cultivation linked to both deforestation and reforestation events is apparent when visualizing the cocoa cultivation trajectory (**Figure 5**). Cocoa cultivation in Irazola, Peru started in the 1980s and followed a cycle of migration, forest

FIGURE 4 | Peru's media outlook (before and after 2010) linking cocoa cultivation to reforestation and deforestation.

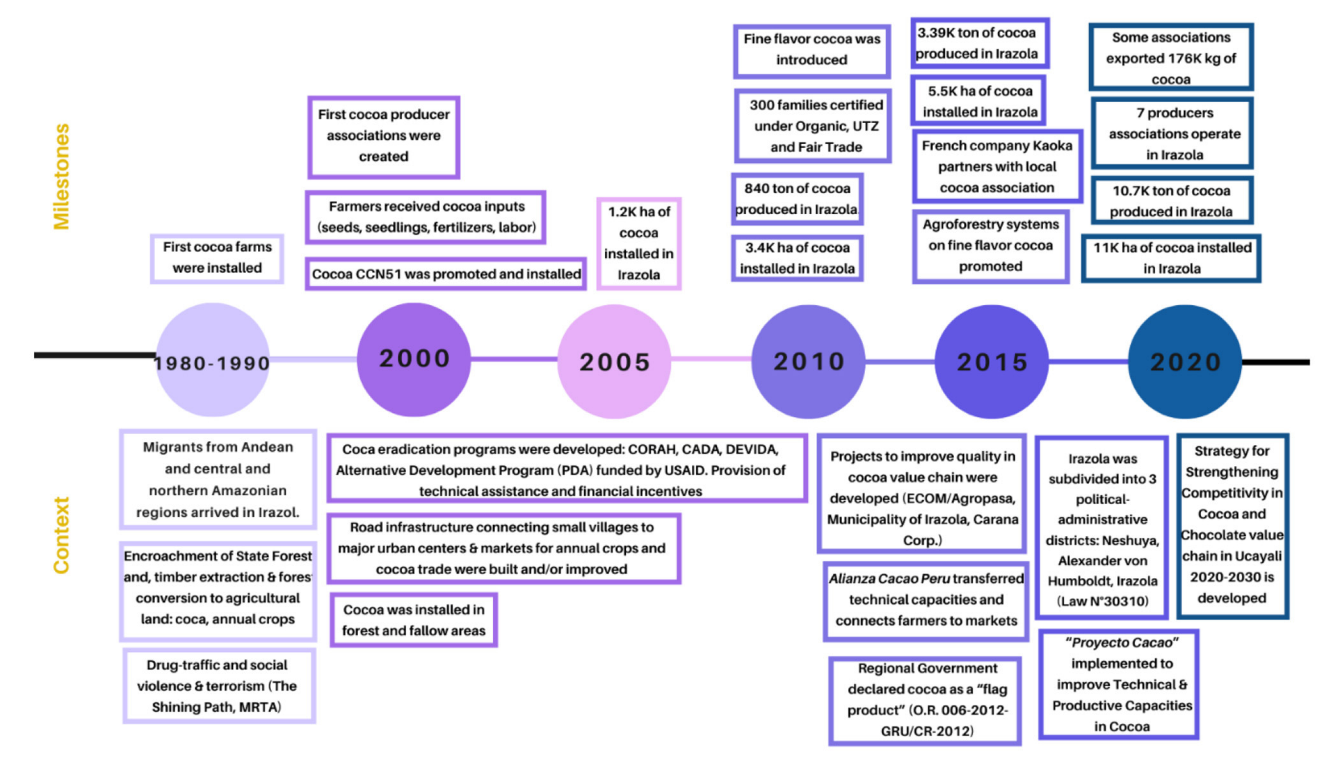

FIGURE 5 | Timeline (milestones and context) of cocoa cultivation in Irazola, Ucayali, Peru.

conversion, and degradation that allowed the establishment of tree-based-crops across the landscape. Between 1980 and 1990, seed-based cocoa plantations were the norm, and the crop expanded into previously deforested land or secondary forests (Gutierrez et al., 2011; Meyfroidt et al., 2014). From 1995 to 2000, drug trafficking, terrorisms, and other social issues discouraged farmers from planting more cocoa and led some to abandon their land and/or started to grow coca instead. In the 2000s specific conditions in the area, such as the existence of national programs focused on the eradication of illicit crops, the development of road infrastructure, and access to markets facilitated the establishment of new cocoa areas. The expansion of palm oil took advantage of infrastructure development and market openness to plant 10k ha. During the same period (2000–2010) about 1,200 ha of cocoa were established, the first cocoa-based organization was founded, and new high-yielding varieties were introduced. Cocoa farming was not a key driver of deforestation.

In the 2010s, cocoa cultivation consolidated its status in the area, so new areas were planted, cocoa certification processes were in place and new market relationships were created between cocoa farmer' organizations and manufacturing industries. The period of bonanza of cocoa cultivation in Irazola lasted from 2005 to 2015. Furthermore, a new niche market was explored or promoted (fine flavor-cocoa). By 2020s Irazola has 11k ha (half the area of cocoa in Nicaragua) and is exporting 1,750 Mt of cocoa. This is the result of sustained aid from national and international projects accompanied by government initiatives and public policies. Alianza Cacao Peru has invested significant funds (an estimated of $85 million over 10 years) to plant, rehabilitate and trade cocoa mainly in San Martin province but its cultivation models, training domains, know-how, and market' links have gone beyond its intervention area and are being adopted elsewhere. Today, Irazola has a strategy for strength the competitiveness of the cocoa value chain while Peru (as key cocoa producing country in the region) has set up national cocoa task force led by the government which is currently reviewing the national plan for the cultivation and trade of fine cocoa 2020–2030.

Analysis of the satellite images of land use/land cover of the Irazola district in the 2000s, shows most of the land in Irazola was covered by undisturbed forests (74%), followed by degraded forests (12%), u pastures (7%), and only 4.3% was occupied by cocoa and shrubs (**Table 6**, **Supplementary Figure 2**). Thirteen years later, the landscape of Irazola has changed remarkably since the area covered by undisturbed forests was reduced by 33%, pastures increased by 157%, the cocoa cultivated area went up 28% while, during the same period, the area grown with oil palm increased 18-fold (nearly 5% of the district). Between 2002 and 2015 more than 1,120 ha of cocoa were established and the crop covered nearly 2% of the district' agricultural landscape. The major drivers of tree cover decline in the Irazola were the expansion of oil palm, small-scale agriculture, and pasture. Cocoa, in contrast, since it is mainly cultivated under agroforestry

TABLE 6 | Land-use change (ha) between 2002 and 2015 in the district of Irazola, Ucayali, Peru.

Land-use type	2002	2015	Change	% of change	% relative to total area
Old growth/undisturbed forest	198,943	133,709	−65,234	−33%	−24%
Degraded forest 65–15%	31,477	30,419	−1,058	−3%	0%
Shrub fallow vegetation	11,570	32,041	20,471	177%	8%
Herbaceous fallow vegetation	4,021	5,144	1,124	28%	1.5%
Perennial crops (oil palm)	659	11,419	10,760	1,632%	4%
Annual crops	669	3,869	3,200	478%	1%
Pasture	17,899	45,963	28,064	157%	10%
Urban area	75	408	333	447%	0%
Transport network	581	2,928	2,347	404%	1%
Water course	2,736	2,730	−6	0%	0%
Total	268,630	26,630			

systems, probably secures tree-cover on agricultural lands thus slowing deforestation processes in some key areas within the Irazola landscape.

DISCUSSION

Cocoa Cultivation and Links to Reforestation and Deforestation in Nicaragua and Peru

Our research suggests that cocoa cultivation in Nicaragua and Peru is linked to both reforestation/deforestation processes and that these phenomena might respond differently to a wide range of stressors and drivers of social, political, and economic nature. For instance, as devised by in-country experts and the media outlook; in Nicaragua cocoa cultivation is almost entirely linked to reforestation since the crop was established in previously deforested areas. Specifically, in Waslala cocoa replaced degraded pasture, old-unproductive coffee plots, and old fallows therefore the crop is enhancing tree cover on agricultural areas within the farms yet, given the extent of cocoa farming at the landscape level, its positive effect on the reforestation process is minimal (compared to the extent of pastureland in the municipality). Under the lens of country experts, cocoa cultivation in Peru growing regions and in Irazola followed three different pathways: first, cocoa might replace forested areas (i.e., purmas or secondary forests) to gain land rights and cash from the sale of timber. Second, cocoa areas might be used to grow annual crops and/or plant and trade transitory fruits trees such as papaya and *Citrus* spp. as a way of facing unemployment in rural areas (Mithöfer et al., 2017a; Wiegel et al., 2020). Third as a response to the government-led colonization-development program and external incentives and forces (i.e., better prices, new cocoa planting material-mainly CCN51-and private investment on agricultural frontiers). In both countries, the crop experienced an increase in area and production (only in Peru), both as a response to national and local context. In other crop-commodities (i.e., coffee), farmers also respond to local context influencing land-use decisions in a territory or landscape (Bosselmann, 2012). Similar stressors/drivers of the reduction/expansion of cocoa have been reported in several cocoa fronts in Colombia and Peru (Castro-Nunez et al., 2020; Pokorny et al., 2021).

The results of this study allowed us to link the conditions/features of the cocoa governance and cultivation models with reforestation or deforestation processes and which conditions generated consensus among experts in both Nicaragua and Peru. The use of the Q method proved useful to account for a wide variety of perspective on complex socio-ecological issues or controversial topics. In this study, a myriad of conditions, including, economic features (i.e., better cocoa prices, incentives), market conditions (i.e., certification and labels, bean quality standards), and political influence of the cocoa board might support reforestation efforts on a given landscape. For example, our findings, show that access to organic market and shaded cocoa planting designs have the potential to support reforestation processes in Nicaragua. However, the international cocoa certification system is highly fragmented; there are multiple schemes for certifying cocoa production yet, the price premium for these certifications is relatively small, and it is still debatable whether the benefits actually accrue to cocoa farmers (Fountain and Huetz-Adams, 2020). Likewise, the aspects of cocoa farming linked to reforestation in Peru were related to the predominant cultivation model (i.e., use of shaded systems) and commercialization (access to specialty market), infrastructure development and political influence. Our results also revealed that political influence (of land-users) combined with market and economic features (certification, price fluctuation, land value, tenure), productive aspects (i.e., aging of cocoa plants) and governance instruments (i.e., national strategy/plans, private investment) may trigger deforestation and expand and replace cocoa with other cash crops and livestock.

Consensus reached by experts in both countries are also in line with the fact that the expansion of cocoa across the countries has been mainly driven by external forces, institutional landscape, and access to finance, yet the sector might be quite sensitive to outer shocks and sudden events, thus cocoa might switch from an agent of reforestation to a driver of deforestation within decades. Besides the significant increase in cultivated areas, the cocoa sector has little relevance and political weight in Nicaragua and in most Central American countries (Somarriba et al., 2008; Orozco Aguilar et al., 2015), whereas in Peru is gaining influence in governmental, non-governmental, and international for development cooperation aid (Technoserve, 2015; Mithöfer et al., 2017b; Wiegel et al., 2020). In both countries, current high prices for cocoa have motivated governments, donors, and NGOs to promote the cultivation of cocoa to reduce poverty in remote, economically depressed regions (Iturrios, 2016; Martorell Mir, 2019; Wiegel et al., 2020).

The media outlooks we built were also in line with this national view of cocoa farming as a key crop for sustainable development in rural Nicaragua and Peru. At the national level, the enforcement of environmental laws might be important in defining the role of cocoa farming as a driver of either deforestation or reforestation (Angelsen et al., 2012; Tscharntke et al., 2011). Few in-country experts interviewed in Nicaragua stated that farmers might replace primary forests to grow cocoa, mainly in remote areas where the environmental regulation is weak or absent. This condition (existence of weak policies related to environment and natural resources management) was also mentioned by Somarriba et al. (2018) as an enabling condition driving forests conversion in buffer zones.

Cocoa cultivation and trade in Nicaragua and Perú have responded positively and neutrally to several incentives, forces, and shocks but the current cultivated area in both countries does not seem to be enough to label cocoa as a major driver of reforestation or tree cover change. However, cocoa cultivation might prevent the expansion of other land uses with less environmental value and landscape restoration potential, therefore conserving tree cover and reducing the pressure on remnant forests. We were able to elucidate the main pathways of cocoa cultivation by combining qualitative and spatial-temporal methodologies that included the Q-method, a media-outlook, land-use change analysis and cocoa cultivation timeline.

Cocoa Expansion and Forest Replacement Pathways in Nicaragua and Peru

According to in-country experts abandoning or replacing cocoa plantations is uncommon in Nicaragua but it might be triggered by incidence of diseases (i.e., moniliasis during the 90s); poor selection of planting material (which was the case in the municipality of Waslala-our study-case site, during the 90s and 2000s); and low coverage of technical services delivered to farmers. Cocoa might replace primary forests mainly in remote areas where environmental regulation is weak or absent. In the case of Peru, from the experts' perspective, cocoa cultivation could be abandoned or replaced by faster and more profitable crops such as oil palm, coca, and Arabica coffee which in turn might trigger deforestation or reduce tree cover at both farm and landscape level (Ganzenmüller and Castro-Nuñez, 2019). Cocoa could also be abandoned due to social issues and drug activities which force families to leave the land, especially in Central and South America where deforestation hotspots and protected areas often overlap with regions of drug production and trafficking (Kaimowitz and Fauné, 2003; Armenteras et al., 2013; Clerici et al., 2020).

Our study is not without limitations. The data we collected represents only one site per country, and did not provide enough geographical and cultivation pathways (i.e., older or newer cocoa fronts, business models across cocoa production areas, and national plans/strategies) to explain the potential role of cocoa cultivation as agent of reforestation or reforestation at country level, yet the combined methodology we described here was useful in pointing out that deforestation and cocoa cultivation cycles need to be carefully analyzed in light of the context where is grown, thus the landscape level is a key unit of analysis (Ruf, 2018; Castro-Nunez et al., 2020).

Cocoa Cultivation Models in Nicaragua and Peru

The cultivation models promoted by development agencies, government bodies, and industry players and described as "shaded systems" are influential in linking cocoa cultivation to reforestation in both countries. In fact, for Nicaragua this was one of the statements upon which all in-country experts agreed. These shade cocoa plantations feature a wide list of shade tree species, arrangements, and designs, and seem to follow a land-sharing theory within the agricultural landscape, yet the nation's current area covered by cocoa is so small that its potential to enhance tree cover, provide landscape connectivity and supports the provision of environmental services over time is modest (Arévalo, 2010; Orozco Aguilar et al., 2015). This land-use configuration of shaded cocoa in Waslala was also in line with the expert's view and the changes and trends reported in both the land cover/land-use maps and the timeline we devised. Indeed, in 1990, cocoa was planted in small patches on alluvial sites where soil fertility met the crop's requirements. The selection of plain terrains to grow cocoa was a technical recommendation made by former technical staff to avoid the potential damage by the wind on steeper sites (Sandino et al., 1999; Stocks et al., 2007). This technical recommendation persisted over time, so the rest of the land was then occupied by extensive livestock, coffee plantations, and subsistence agriculture (Philipp and Gamboa, 2003).

In Peru, the cocoa cultivation model promoted by private investors and access to specialty markets and other financial incentives could have a significant role in defining the potential of cocoa cultivation to enhance tree cover. Experiences in Brazil, Ecuador, and Colombia where cocoa farming is restoring degraded lands support this argument (Tscharntke et al., 2015; Schroth et al., 2016a; Middendorp et al., 2018). In the south of Pará state, Brazilian Amazon, the adoption of shaded cocoa by farmers and ranchers is stimulated by favorable conditions such as attractive national and international prices, the expectation of a global cocoa supply gap; environmental policies obliging landowners to reforest excess cleared land with native trees and biophysical conditions favorable for growing cocoa in part of the region (Schroth et al., 2016c). According to available technical reports from both selected sites (Fréguin-Gresh et al., 2016; Marquardt et al., 2019) and framed in the forest trasntition curve theory, is sound to say that the agricultural lanscape in the Waslala municipality is under the "recovery phase" where new cocoa plots being established are potentially labeled as a reforestation effort; while the landscepe of Irazola district is still under the "tree cover decline" phase so any tree cover loss, trigger by either the expantion of cocoa or other annual or perennial crops, is potentially seem as a deforestation event (Barbier et al., 2010; Dewi et al., 2017).

The trend of land-use change in the district of Irazola was in line with expert's opinions and well supported by the spatial-temporal analysis we conducted and the cultivation timeline we devised. In response to the rapid expansion of oil palm, livestock, and cocoa as well, the national media outlook we compiled shown how the government looked at the issue of cocoa farming and deforestation and started enforcing the environmental law on large-scale cocoa farms. This law enforcement by the Peruvian government is a crucial step toward safeguarding the role of cocoa cultivation as a driver of reforestation and restoration, especially over ecologically fragile ecosystems like the Peruvian Amazon. The existence of a national cocoa strategy and the ongoing international aid in Peru are indicative that cocoa cultivation in Irazola and other cocoa fronts across the country will increase in the next 5 years, yet the extent, expansion rate and the effects on tree cover change remain unknown. Over time, cocoa cultivation in Irazola has responded negatively and positively to several incentives/forces and the current cultivated area and land use trend seem to be not enough to label cocoa farming as major driver of reforestation. Similar trends are reported for coffee growing areas in Colombia where certified coffee acted as enhancer of tree cover and forest connectivity (Rueda et al., 2014).

CONCLUSION

Cocoa cultivation in Nicaragua and Peru can be a driver of both deforestation and reforestation. Its potential to enhance tree cover relies on the extent of occurrence and spatial distribution patter across any agricultural landscapes. Our research suggests that cocoa cultivation in both countries responded differently to a wide range of stressors and drivers of social, political, and economic nature. Depending on particular contexts and the occurrence of sudden events along the value chain, cocoa can switch from the status of deforestation agent to one of reforestation agent. The Q-method combined with land cover/land-use maps and cultivation timeline we applied was a helpful approach to identify the pathways, enabling and limiting conditions driving cocoa cultivation and deforestation/reforestation processes. The outcomes of this research could aid informed decisions among cocoa actors to (a) debate on the most suitable and profitable cocoa agroforestry for organized farmers (b) formulate policies for sustainable cocoa cultivation at large scale and (c) assess feasible landscape restoration opportunities to minimize the deforestation footprint of cocoa cultivation and maximize its role as reforestation agent in Latin American.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Materials**, further inquiries can be directed to the corresponding authors.

AUTHOR CONTRIBUTIONS

LO-A and AL-S designed the study, wrote the first draft of the manuscript, and contributed equally to the final version of the manuscript. VR, MB, MR, and NS collected the data and created the maps. MB and ML-M collected data for the media outlook. AL-S, LO-A, ML-M, and MB analyzed the quantitative data. VR, MR, and ES contributed to the discussion and conclusion. All authors contributed to the article and approved the submitted version.

FUNDING

This research was carried out by Maximizing Opportunities for Coffee and Cacao in the Americas Project-Maximizing opportunities for coffee and cocoa in the Americas (FCC-596-2018/005-00) in coordination with CATIE as part of the CGIAR Research Program on Forests, Trees and Agroforestry (FTA). FTA is the world's largest research for development program to enhance the role of forests, trees, and agroforestry in sustainable development and food security and to address climate change. CIFOR leads FTA in partnership with Bioversity International, CATIE, CIRAD, INBAR, ICRAF, and TBI. FTA's work was supported by the CGIAR Trust Fund: cgiar.org/funders/.

ACKNOWLEDGMENTS

We are grateful to the 33 in-country cocoa experts for collaborating with this study and feedback provided. We also thank the assistance of Emma Rojas Sampson and Melissa Orozco Lopez in re-drawing the cocoa typologies and the cocoa cultivation timelines presented in this article. We are thankful to Karen Baltodano from INETER for providing land use maps for Waslala, Nicaragua. We finally thank Gifford Laube and Carolina Aguilar from Lutheran World Relief for their valuable feedback on previous versions of the manuscript.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2021.635779/full#supplementary-material

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.