



Under what conditions do payments for environmental services enable forest conservation in the Amazon? A realist synthesis

Fernando-Esteban Montero-de-Oliveira ^{a,b,c,*}, Genowefa Blundo-Canto ^{a,b}, Driss Ezzine-de-Blas ^d

^a CIRAD – UMR Innovation, Montpellier Cedex 5, France

^b Univ Montpellier, F-34090 Montpellier, France

^c Chair of Silviculture, Faculty of Environment and Natural Resources, University of Freiburg, Tennenbacherstr. 4, 79085, Freiburg, Germany

^d CIRAD, Unité Propre de Recherche Forêts et Sociétés (FORETS), Campus de Baillarguet, 34090 Montpellier, France

ARTICLE INFO

Keywords:

Conservation incentives
Tropical forests
Payments for ecosystem services
Impact
Realist synthesis

ABSTRACT

Payments for environmental services (PES) have been widely studied as one possible way to counter deforestation and support livelihoods. Given the high rates of deforestation in the Amazon region, it is important to study under which conditions PES have positive environmental and social outcomes. We contribute to this debate through a systematic review based on the Realist Evaluation framework. First, we review case studies to identify configurations of social-ecological factors (context), PES design and implementation (resource mechanisms), people's responses (reasoning mechanisms), and the results in terms of forest conservation and people's livelihoods (outcomes). Second, we develop a middle-range theory of how, for whom, and under what conditions PES in the Amazon achieve these results. After screening 972 articles in the SCOPUS, Scielo, and WorldCat databases, we reviewed 13 articles in-depth that contained all the elements (context-mechanism-outcomes) needed to identify these configurations. Our results show that PES in the Amazon generate positive environmental and social outcomes when they: (a) combine cash and in-kind incentives, (b) raise environmental awareness through capacity building, (c) engage socially and ethnically diverse stakeholders through equitable and inclusive approaches, (d) apply transparent spatial targeting, (e) guarantee strong conditionality through robust monitoring of compliance, and (f) guarantee stable delivery of payments.

1. Introduction

The conversion of tropical rainforests for agriculture and livestock production contributes significantly to global anthropogenic greenhouse gas emissions (FAO, 2020; IPCC, 2019). Local people who rely on forests for a variety of benefits are often the most affected by changes in forest cover and quality (Andersson et al., 2018; Börner et al., 2013; Gebara, 2013). In the Amazon region, which hosts the Amazon rainforest and is one of the most biodiverse places on earth, forest loss is both substantial and on the rise (FAO, 2020). Two-thirds of the Amazon region are located in Brazil, and the remaining third is distributed between Colombia, Peru, Ecuador, Bolivia, Venezuela, Guyana, Suriname, and French Guiana. Brazil is the country with the highest average annual net forest loss worldwide (FAO, 2020), and, despite a decline between 2003 and 2015, deforestation figures reached decadal records in 2020 (Silva Junior et al., 2021). Peru reached record levels between 2000 and 2014 (Potapov et al., 2014), along with significant losses in Ecuador, Bolivia,

Venezuela, Guyana, Suriname, and French Guiana (Hansen et al., 2013, 2020). The governments of these countries have been implementing incentive-based forest conservation approaches, including Payments for Environmental Services (PES), to reduce deforestation, mitigate climate change, conserve biodiversity, and ultimately improve forest-dependent livelihoods and reduce rural poverty (Giudice and Börner, 2021).

Indeed, since a number of PES originated with a social purpose as their main objective, achieving both environmental and social objectives has been part of their strategy (Corbera and Pascual, 2012; Shapiro-Garza et al., 2020). PES programs have sometimes been found to cause net livelihood losses to service providers (Brimont et al., 2017). The evaluation of social, cultural and institutional capacities (Hejnowicz et al., 2014) and outcomes of PES for heterogeneous providers and users (Blundo-Canto et al., 2018) are a recurrent research gap. The number of PES implemented far outpaces their evaluation (Samii et al., 2014), meaning there is a gap in the empirical basis for attributing changes in poverty to PES (Pattanayak et al., 2010). Non-transparent program

* Corresponding author.

E-mail address: esteban.montero@waldbau.uni-freiburg.de (F.-E. Montero-de-Oliveira).

<https://doi.org/10.1016/j.ecocon.2022.107697>

Received 1 April 2022; Received in revised form 3 September 2022; Accepted 23 November 2022

Available online 10 December 2022

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design also affects the results of PES (Hayes et al., 2019). Spatial targeting –i.e. selecting PES areas based on the density of environmental services and social indicators such as poverty levels– is another key weakness affecting cost efficiency and environmental outcomes (Ezzine-De-Blas et al., 2016). Indeed, the impact of PES implemented in areas where pressure on natural resources is low can be limited (Börner et al., 2020). Previous systematic reviews including PES schemes carried out in the Amazon region found that their performance is often hindered by equity-related issues in the design and distribution of payments (Calvet-Mir et al., 2015; Perevochtchikova et al., 2021). Conversely, long-term contracts, in-kind benefits, and direct interaction between environmental service providers and users have been linked to PES with higher chances of success in Latin America (Grima et al., 2016). Behavioral aspects (Bauchet et al., 2020) such as pro-social and pro-environmental attitudes (Jones et al., 2020) seem to influence successful participation in PES. Lack of systematic reporting, monitoring and evaluation of PES schemes has also been identified as a key gap in programs in this geographical area (Martin-Ortega et al., 2013; Salzman et al., 2018).

The diversity of evidence in the literature calls for more studies to establish causal relationships between the context in which the intervention is implemented, its design, and its outcomes (Börner et al., 2017). In this review, we focus on making explicit the mechanisms underlying PES implementation in the Amazon and apply a framework that allows us to reveal mechanisms of success or failure by answering the question “What works, how, why, for whom, to what extent, and in what circumstances?”, which is at the center of the Realist Evaluation approach (Lemire et al., 2020; Pawson and Tilley, 1997). To this end, we applied the realist synthesis method, i.e., a systematic literature review that makes it possible to summarize evidence in terms of interactions between contexts, mechanisms, and outcomes (Wong et al., 2013). The realist synthesis adds the explanation of causality mechanisms from a theoretical perspective to guide the systematization of the papers reviewed. Focusing on the interaction between the context in which a PES is implemented, the features of PES programs, and human responses, we develop a middle-range theory (Pawson and Tilley, 1997; Vigneri, 2021) of the conditions under which PES produce desirable environmental and social outcomes in the Amazon. Our aim is not to categorize specific initiatives in terms of their relative success or failure vis-à-vis self-declared or donor-determined objectives. Rather, our aim is to develop a partially generalizable theory on the interaction between context, resource, and reasoning mechanisms that explain the different social and environmental outcomes of PES schemes in the Amazon.

In the following sections we present key concepts of realist evaluation that guide our systematic review; we then present the results of our review and discuss them in light of the conditions under which PES in the Amazon enable desirable outcomes.

2. Conceptual framework

Realist evaluation is about testing and refining a theory through iterations between theorization and empirical observations using both inductive and deductive reasoning (Astbury and Leeuw, 2010; Pawson and Tilley, 2004). Four key concepts are used in realist evaluation and hence in realist synthesis: ‘mechanism’, ‘context’, ‘outcome’, and Context-Mechanism-Outcome configuration (C-M-O).

2.1. C-M-O configurations

A C-M-O configuration is a hypothesis stating what works, for whom and in what circumstances (Pawson and Tilley, 2004). An outcome (O) of interest is generated by relevant mechanisms (M) that are triggered in a given context (C). In a realist synthesis, recurrent patterns of outcomes (or demi-regularities) and their associated mechanisms and contexts (C-M-O) are expected within or across the documents analyzed (Wong et al., 2013).

2.1.1. Mechanisms

Causal mechanisms in realist evaluation focus on why people do what they do and how different contexts enable different mechanisms, and consequently different causal regularities (Vigneri, 2021). Therefore, mechanisms are made of the program’s resources interacting with human reasoning that will trigger or activate particular behaviors or responses in a given context (Wong et al., 2013). These mechanisms exist whether they are activated or not. They are triggered under certain conditions and generate change based on the choices, reasoning, and decisions people make, given the program’s resources and context (Punton and Vogel, 2020).

In this study, we differentiate the two parts of a mechanism as suggested by Dalkin et al. (2015): the resources provided by the program represent the resource mechanism, and human reasoning that can be activated or not, represents the reasoning mechanism (Fig. 1). In the case of PES, the resources offered by the program include its intended treatments, e.g. conditional cash transfers; stakeholder engagement; capacity building; governance rules; monitoring and sanctioning. Introduced in a particular context, the aim of the treatments is to activate human reasoning and trigger behavioral responses that generate environmental and socio-economic outcomes. Behavior may vary according to how people interpret biophysical, economic, and political signals in their decision-making (Simmons et al., 2021). For instance, PES resources can influence the cultural and economic values that local communities attach to forests, encouraging them to continue their current behavior or to change it (Gebara, 2013).

2.1.2. Context

Realist evaluation uses contextual thinking to address the issues of ‘for whom’ and ‘in what circumstances’ an intervention will succeed. The context includes individual characteristics that affect how people respond to opportunities (e.g. gender, ethnicity, education), interpersonal factors that affect trust and buy-in (e.g. relationships between stakeholders and program implementers), institutional factors (rules, norms, and culture of the system in which the intervention is implemented), and infrastructural factors (the wider social, economic, political and cultural setting) (Pawson and Tilley, 2004, p.4).

It is also important to think about how different layers of context interact with each other, rather than simply providing a description of each layer, considering that context is time-sensitive (Greenhalgh and Manzano, 2021). Outcomes are related to a set of mechanisms triggered in a specific context: over time, the context may change and trigger a separate set of mechanisms that in turn trigger changes in outcomes.

Our aim was to understand how context interacts with mechanisms and consequently affects the outcomes of PES. Values, beliefs, attitudes, preferences, habits, cost and benefits, social norms, policies, and institutions are all complex factors that may influence behavior and are often underestimated when deforestation outcomes are assessed (Reddy et al., 2017).

2.1.3. Outcomes

Outcomes are the practical effects produced by causal mechanisms that are triggered in a given context (Lemire et al., 2020). They are the intended and unintended consequences of interventions (Sarmiento Barletti et al., 2020). As an illustration, increased access to education and health services (Agustsson et al., 2014; Börner et al., 2013) and increased deforestation levels (Etchart et al., 2020; Giudice et al., 2019), have all been found to be environmental and social outcomes of PES programs in the Amazon.

2.1.4. Middle-range theory

A middle-range theory defines empirical regularities in human behavior and the causal patterns observed in different settings (Vigneri, 2021). First, a theory must be sought, developed, or refined to explain how it is that an intervention (e.g. PES in the Amazon) produces outcomes (e.g. environmental and societal outcomes) and the contexts in

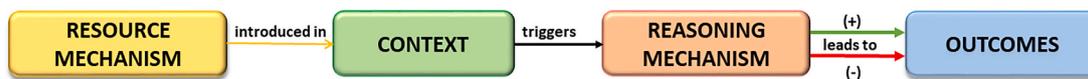


Fig. 1. Context-Mechanism-Outcome configuration (adapted from Dalkin et al., 2015).

which these mechanisms are activated. Second, at a more general level, the regular, repeated patterns of C-M-O configurations need to be identified to develop or refine the initial theory (Wong et al., 2013).

3. Methods

3.1. Document search

To select the documents to be reviewed, we applied the PRISMA guidelines (Page et al., 2021). We conducted a comprehensive search for peer-reviewed studies on PES in the Amazon in the electronic databases Scopus (title, abstract, and keywords search) and Scielo (title, and abstract search). As grey literature, we consulted OAIster/WorldCat. Given the different archiving systems of these databases, the search terms used were “payments or rewards for environmental or ecosystem services” AND “Amazon or Bolivia or Brazil or Colombia or Ecuador or Peru or Venezuela or Suriname or Guyana/Guiana”. We did not specify the type of document, language, or year of publication. After this initial selection, we used a “snowball” approach when documents responding to the selection criteria were cited in the documents selected (usually previous systematic reviews) but did not appear in the databases we searched (Wong et al., 2013). The dates the search was conducted span from May 21, 2021 to June 1, 2021. Fig. 2 shows the selection and inclusion approach we used, and S1 Table details the databases consulted, the

search terms used for each database, and the final number of records included after removing duplicates.

The inclusion criteria were the following: (1) the PES program has an explicit component of conditionality -i.e. a contract or an agreement that conditions payments (in-kind or cash) and technical assistance in the fulfillment of specific conditions (Ezzine-De-Blas et al., 2016; Muradian et al., 2010; Wunder et al., 2020); (2) the paper includes an evaluation of an implemented PES (summative/ex-post or formative evaluation of the environmental or societal impacts of the PES); (3) the data collection methods are clearly described; (4) the PES scheme was implemented in the Amazon basin; and (5) all the elements of the C-M-O configuration are identifiable in the paper (sufficient information about the local context in which the program was applied; resource mechanisms are explicit; reasoning mechanisms present or easily inferable; and outcomes analyzed).

After removing duplicates and reading all 974 titles and abstracts, we screened 950 records, among which we identified 24 eligible for full-text assessment. The snowball approach identified a further 15 eligible texts giving a total of 39 studies for full-text assessment. The final sample of documents included 13 articles presenting 14 case studies. Five of the finally included papers were found using the snowball approach (see Fig. 2 and S1 Table). The S2 Database contains all 39 eligible studies for full-text assessment and corresponding filtering criteria.

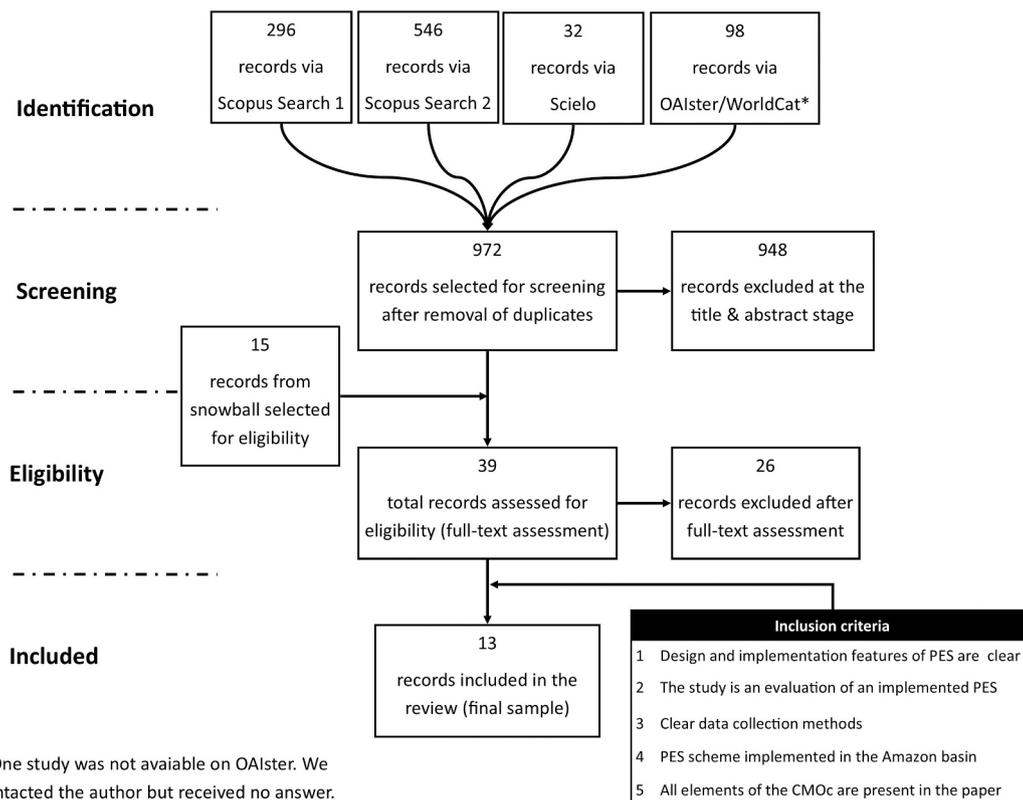


Fig. 2. PRISMA flowchart for the identification and selection of PES schemes included in the study. Scopus Search 1 included affiliated countries that share the Amazon rainforest. Scopus Search 2 included the term “amazon*” but not limited to affiliated countries.

3.2. Document characteristics

Here we provide a brief overview of the general trends of the given studies reviewed. Details on the 13 publications included key features of the PES evaluated, and the methods used by the studies to evaluate them are provided in the S2 Database.

The 13 papers cover 14 case studies referring to six PES interventions in four countries located in the Amazon basin: Bolsa Floresta (5 case studies) and Proambiente (2) in Brazil, Socio Bosque (3) in Ecuador, Noel Kempff Mercado Climate Action Project (2) in Bolivia, and Moyobamba PES (1) and Conditional Direct Transfer (1) in Peru. In three PES schemes, the modes of payment were cash and in-kind payments, followed by only in-kind (2), and one scheme providing only cash transfer. ES users were mainly national governments (3 PES), and ES providers were mainly individual and community landowners (3). In three PES schemes ES targeted were multiple services from agricultural landscapes, followed by climate change mitigation (2), and watershed protection (1). Contractual conditionality was environmental (5 PES), and both social and environmental (1). The evaluation methods applied in the assessments rely on qualitative methods (5 studies), mixed methods (5), and quantitative methods (3). Only four papers compare outcomes for participants and nonparticipants.

4. Analysis and synthesis

Realist synthesis combines deductive theory building with inductive updating and refining in an iterative way. Using this approach, we first conceptualized the generic C-M-O configuration in the context of PES (Fig. 3) to guide the analysis of the papers included in the review. The purpose of the review is to update and refine this generic conceptualization with the results of the analysis. To define the initial generic C-M-O configuration, we drew on the literature on PES (e.g. Hejniewicz et al., 2014; Wunder et al., 2008, 2020) to define resource mechanisms and outcomes, and on behavioral theories and realist syntheses in

environmental conservation to define reasoning mechanisms and context variables (e.g. Miljand et al., 2021; Simmons et al., 2021), (the full list of references is available in S3: Analysis grid for C-M-O components). Fig. 3 shows this generic conceptual framework, based on the literature presented in S3 and updated with the elements found in the 13 papers reviewed.

The guiding conceptual framework shows how multiple dimensions of the context, such as degraded natural forests, interact with demographic, cultural and institutional dynamics, environmental policy measures, elements of PES design, and behavioral responses of people, leading to social, economic and environmental outcomes.

4.1. Theory building

We started by deducing a PES generic C-M-O configuration from the literature, which we tested and refined through the analysis of our results and then used to develop our middle-range theory for PES in the Amazon. Following a deductive and inductive approach, we iteratively defined a list comprising Context, Resource Mechanism, Reasoning Mechanism, and Outcomes, and their related variables (e.g. Controllability and sense of autonomy for Reasoning) and modalities (e.g. Participants' perception that the PES will reduce their control over land-use decisions for the same Reasoning). The final list of dimensions and definitions are provided in S3 Table. The modalities were identified, coded, and stored in the software ATLAS.ti 9 Windows.

To analyze our data, we applied three levels of analysis of the C-M-O configurations: 1) case study, 2) PES program, 3) cross programs.

First we identified and coded each element of the C-M-O configurations in each case study. We then wrote a narrative for the C-M-O configurations found in each paper, each with a visual representation and text quotes. For instance, in a context of high ethnic heterogeneity (contextual modality) a PES program that is characterized by inequitable participation (resource mechanism modality), triggers a low sense of ownership and a perception of unfairness (reasoning mechanism

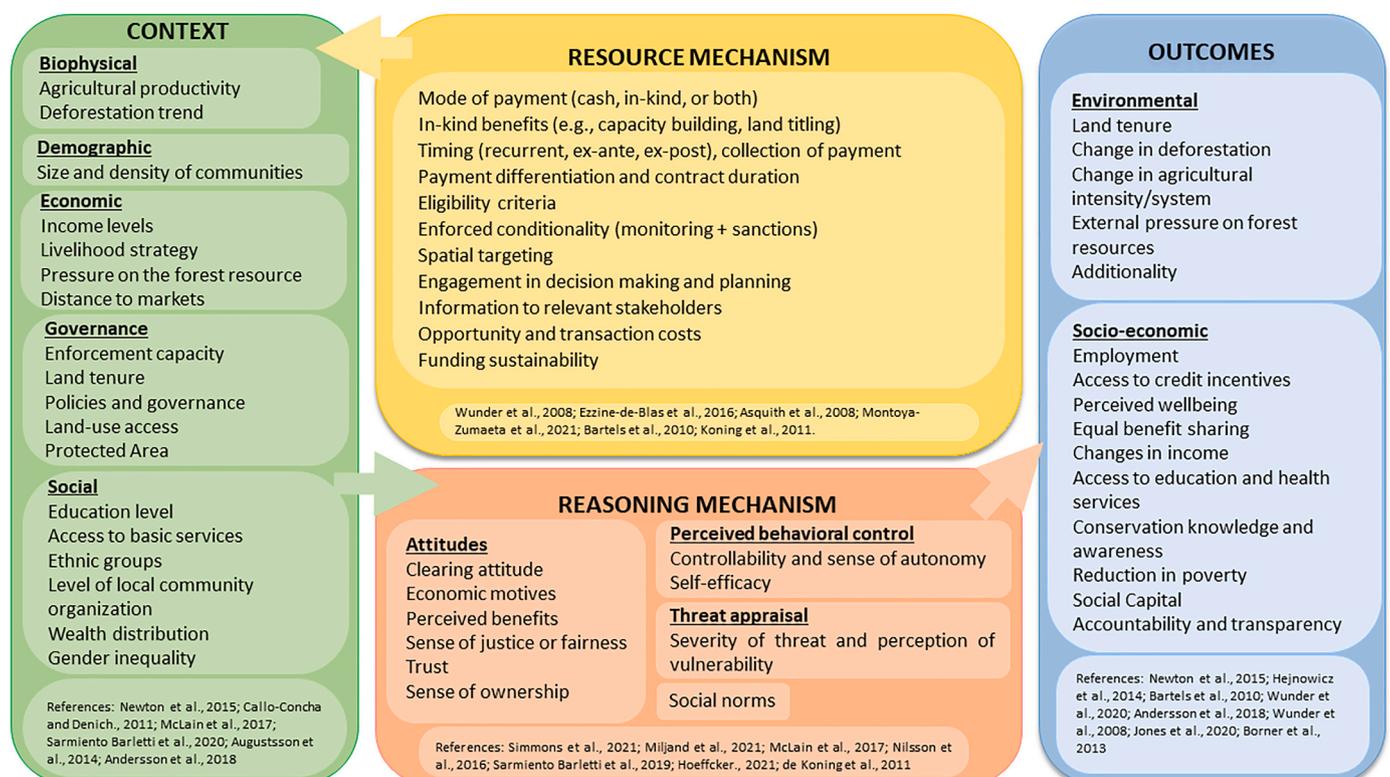


Fig. 3. Conceptual framework of the realist synthesis. The complete list of references used for identifying the variables in each element of the configuration are provided in S3 Table.

modalities), ultimately leading to unequitable benefit distribution (outcome). Next, we combined the C-M-O configurations for each PES program to identify converging and diverging findings for a given PES. We did this by selecting among the causal configurations linked to the reasoning mechanisms that appeared most frequently across programs. Finally, we combined the C-M-O configurations across programs and developed the middle range theory by identifying regular patterns in the way PES generate outcomes.

We defined positive and negative outcomes as they were presented in the case studies, e.g. inequitable benefit distribution is a negative social outcome while increased access to education and health services is a positive outcome. On the other hand, avoided deforestation on enrolled land and increased deforestation on both enrolled and non-enrolled land are positive and negative environmental outcomes, respectively.

5. Results

5.1. Main contexts, mechanisms and outcomes

We identified a total of 116 modalities distributed among the C-M-O elements: context (32), resource mechanisms (30), reasoning mechanisms (24), and outcomes (30). The classification of these modalities (e.g. assigning a modality to a citation) in all the case studies resulted in a total of 283 modalities, of which 31% are context, 34% are resource mechanisms, 15% are reasoning mechanisms, and 20% are outcomes. The Bolsa Floresta and the Socio Bosque PES together account for 66% of the total modalities (Table 1).

PES case studies in the Amazon combine resource mechanisms such as payments in cash and in-kind (3 PES) and a guided engagement approach (3) but appear to deliver unequal information to stakeholders (5). They are implemented in contexts where livelihood strategies are subsistence-oriented (3 PES) and in protected areas (3), with low deforestation rates at the onset (3) despite pressure from road construction (3). Moreover, ES providing communities are often isolated from markets (2 PES) and land tenure security is low (3). A pro-environment attitude (3 PES) as well as the perception that PES monetary benefits are advantageous (3) appear to be most common reasoning mechanism, along with a low sense of ownership (2) and perception of unfairness in PES design or implementation (3). Finally, unequal benefit distribution (3 PES) and increased access to education (2) are relatively common outcomes. Inconsistent deforestation outcomes were identified (4). The main modalities found for each element are listed in Table 2.

5.2. The context-mechanism-configurations found in the PES programs that we assessed

Below we briefly describe each of the six PES programs and the C-M-O (context-mechanism-outcome) configurations we drew from them. Instead of presenting all the elements of the context, the mechanisms, and the outcomes we identified in the papers, we only present those elements that interact and generate C-M-O configurations according to our interpretation. Below, we describe configurations such as the Resource Mechanism modality (ResoM), the Context modality (Cont), the Reasoning Mechanism modality (ReasM) and the Outcome modality (Out).

Table 1

Modalities found for each C-M-O element in each PES program. Legend: number of studies in each program (n).

	Bolsa Floresta Brazil (n = 5)	Socio Bosque Ecuador (n = 3)	Noel Kempff MCAP Bolivia (n = 2)	Proambiente Brazil (n = 2)	Moyobamba PES Peru (n = 1)	Conditional Cash Transfer Peru (n = 1)	Total (n = 14)
Context	39	25	12	4	5	2	87
Reasoning mechanisms	13	13	4	8	4	1	43
Resource mechanisms	40	22	7	13	9	6	97
Outcomes	28	7	10	6	3	2	56
Total	120	67	33	31	21	11	283

5.2.1. The Proambiente program in Brazil

Proambiente is a government-run rural program for the Brazilian Amazon that re-values traditional rural livelihood systems while rewarding sustainable land stewardship. The program introduced incentives and capacity building to enhance forest management by smallholders, using guided engagement approaches. Although the program was designed to be implemented in six phases over 15 years, it started in 2003, and was first evaluated in 2006 (Bartels et al., 2010), and again in 2008 (Vasconcellos and Sobrinho, 2012). Chronic challenges persist to the implementation of the Proambiente program, including the establishment of legal frameworks, operational mechanisms, and the definition of sufficient incentives (Simonet et al., 2019; Superti and Aubertin, 2015).

The studies we reviewed focus on the Acre and Rio Capim intervention areas, where livelihood strategies are based on diversified subsistence agriculture (Cont) with a few commercial crops, and where some households have easy access to markets (Cont), whereas others are isolated and consequently do not. In this context, Proambiente PES introduces cash and in-kind payments (ResoM) for individual smallholders and communities in exchange for compliance with environmental guidelines and signed collective agreements (ResoM), applying a professional guided engagement approach (ResoM), in which drafts and plans are drawn up by external professionals (see definition in S3 Table) (Inoue, 1998). This approach had both positive and negative outcomes. Unequal participation in the PES in some communities (Out), due to preexisting power imbalances (Cont) that were reinforced in the way the program supported access to credit, led to a perception of unfairness in some participants (ReasM), especially among local people who have lived in the area for a long time, ultimately leading to unequitable benefit distribution (Out). Moreover, participants were selected based on their membership in a social organization (ResoM), which also led nonparticipants to perceive PES rules as unfair (ReasM). On the other hand, the engagement approach fostered conservation awareness (Out) and reinforced the existing pro-environment attitudes of some participating communities (ReasM). The capacity building (ResoM) provided by the program fostered dialogue within some communities, resulting in higher network ties (Out). However, the financial instability (ResoM) of the program caused general frustration that led participants to not trust the PES implementers (ReasM). In addition, the suspension of payments (ResoM) resulted in downsized staff (Out) and only a temporary increase in income for the participants (Out).

5.2.2. The Moyobamba PES in Peru

Peru's oldest watershed protection initiative is based in the Moyobamba Andes–Amazon transition zone. Following the creation of a protected area, voluntary contracts with conditional in-kind rewards and access to sustainable income-generating activities were introduced using a guided engagement approach. The Moyobamba PES started in 2004 and was evaluated in 2016 (Montoya-Zumaeta et al., 2019).

In the context of small farmers who practice commercial oriented agriculture in a recently created protected area (Cont), the Moyobamba PES produced positive measurable effects on income and assets for participants by providing capacity building (ResoM) to diversify their sources of income. Yet participants perceive they are worse off than before the PES (ReasM). This is related to the perceived strictness of PES

Table 2
The main modalities found for each C-M-O element.

CMO element	Modalities	BF (n = 5)	SB (n = 3)	NK (n = 2)	PA (n = 2)	MPES (n = 1)	CCT (n = 1)	Count	Total	%
RESOURCE MECHANISM	Information or engagement is not equal among stakeholders	1	3	2	1	1	0	5	8	0,57
	Cash transfer + in-kind	5	0	0	2	0	1	3	8	0,57
	Monitoring is weak	4	0	0	1	1	1	4	7	0,50
	Engagement through professional-guided approach	4	0	0	2	1	0	3	7	0,50
	Capacity building provided	3	0	1	2	0	0	3	6	0,43
	Both social and environmental conditionality	5	1	0	0	0	0	2	6	0,43
	Environmental conditionality	0	2	0	1	1	1	4	5	0,36
	Sanctions occasionally applied	1	1	0	0	0	1	3	3	0,21
	Unsustainable funding source	0	1	0	1	1	0	3	3	0,21
Only in-kind benefits	0	0	2	0	1	0	2	3	0,21	
CONTEXT	Livelihood strategy subsistence-oriented	5	2	0	2	0	0	3	9	0,64
	PES inside a Protected Area	5	0	2	0	1	0	3	8	0,57
	Deforestation rate is low	3	0	0	0	1	1	3	5	0,36
	Pressure from road-construction	3	1	0	0	1	0	3	5	0,36
	Land tenure security is low	2	1	2	0	0	0	3	5	0,36
	Access to markets is difficult	4	1	0	0	0	0	2	5	0,36
	Low population density	2	1	1	0	0	0	3	4	0,29
	Income level is low	2	0	2	0	0	0	2	4	0,29
	Agricultural productivity is low	1	2	0	0	0	0	2	3	0,21
	Pressure from land-grabbers and illegal loggers	2	1	0	0	0	0	2	3	0,21
	REASONING MECHANISM	Participants perceive monetary benefits as advantageous	3	0	1	0	0	2	3	6
Pro-environment attitude		1	0	0	0	2	2	3	5	0,36
Participants perceive the PES rules or implementation as unfair		0	0	0	1	1	1	3	3	0,21
Participants feel low sense of ownership		0	0	0	2	0	1	2	3	0,21
PES rules perceived as too strict to comply by part and nonpart		0	1	0	0	0	2	2	3	0,21
Participants perceived monetary benefits as not advantageous		3	0	0	0	0	0	1	3	0,21
Non-monetary payments drive the decision to comply		1	0	0	0	1	0	2	2	0,14
Participants do not trust the PES scheme or its implementers		0	1	0	0	1	0	2	2	0,14
Anti-clearing attitude		1	0	0	0	0	0	1	1	0,07
Monetary and non-monetary payments drive compliance		1	0	0	0	0	0	1	1	0,07
OUTCOME	Not equitable benefit distribution	0	1	2	1	0	0	3	4	0,29
	Increased access to education	3	0	1	0	0	0	2	4	0,29
	Higher network ties	1	0	1	1	0	0	3	3	0,21
	Perceived worsened wellbeing	2	0	0	0	1	0	2	3	0,21
	Decreased external forest pressure on enrolled land	2	0	1	0	0	0	2	3	0,21
	Increased access to health services	2	0	1	0	0	0	2	3	0,21
	Decreased deforestation on enrolled land	1	1	0	0	0	0	2	2	0,14
	Increased income for participants	1	1	0	0	0	0	2	2	0,14
	Lower network ties	1	0	0	0	1	0	2	2	0,14
Increased deforestation on both enrolled and non-enrolled land	1	0	0	1	0	0	2	2	0,14	

Legend: number of studies in each program (n), the Bolsa Floresta Program (BFP), Socio Bosque (SB), Noel Kempff Mercado Climate Action Project (NK), Conditional Cash Transfer (CCT), Moyobamba PES (MPES), Proambiente (PA), Frequency of modalities per program (Total), Number of programs in which modalities appear (Count). The proportion of case studies in which modalities were found (%). Modalities not counted (0) mean no information was found on that modality in the study concerned.

rules (ReasM) (e.g. withdrawable land rights in the case of repeated non-compliance) that led participants to perceive higher land tenure insecurity (ReasM). Despite the professional guided engagement approach (ResoM), information was not provided equally to all participants (ResoM), which reduced some participants' trust in the PES implementers (ReasM). The lack of trust was reinforced by the instability of funding sources (ResoM) that affected payments. Indeed, economic motivations linked to the significant incentives proposed drove the decision of many participants to enroll and became embodied in beneficiaries' future expectations (ReasM). Ultimately, sanctions were applied (ResoM), but a weak monitoring system based on self-reported information (ResoM), focused on delivery of benefits to signatory households rather than on environmental compliance (ResoM), in addition to fluctuating funding (ResoM), resulted in small albeit significant avoided deforestation on enrolled land (Out), also linked to the low deforestation rate at the onset (Out).

5.2.3. The Noel Kempff Mercado Climate Action Project

One of the largest carbon sequestration schemes undertaken globally, this PES-like project aims to avoid carbon-dioxide emissions through avoided deforestation for agriculture and logging, while investing in community development in and around the Noel Kempff Mercado National Park, in northeastern Bolivia. Implemented in 1996 by the Bolivian Government, the Nature Conservancy, and a consortium of private companies, key components of the project were compensation to previous concessionaires and the creation of a park protection endowment fund. The program was evaluated in 2000 (Asquith et al., 2002), and in 2001 (May et al., 2004).

The expansion of the park (Cont) first reduced employment (Out) when the timber concessions ceased activities, followed by new employment opportunities (Out) introduced by the PES for forest management, monitoring, and tourism. However, due to the top-down engagement approach to the PES (ResoM), locals were unequally

informed about the park expansion (ResoM), generating a perception of unfairness in the implementation process, resentment, and a low sense of ownership (ReasM), resulting in inequitable distribution of benefits (Out). Moreover, the PES was initially perceived as a threat by indigenous people (ReasM) who, given the non-inclusive engagement approach (ResoM), feared they would lose access to their traditional land (ReasM). This was mitigated by PES implementers through community development in the form of land-titling projects, among other in-kind benefits (ResoM), ultimately fostering increased land tenure security (Out) and higher network ties (Out), as well as enhancing access to education and health services (Out).

5.2.4. The Conditional Cash Transfer (CCT) program in Peru

The National Forest Conservation Program in Peru was introduced in 2009 for the conservation of tropical forests and the generation of income for the most vulnerable, poor, and marginalized people. A Conditional Cash Transfer (CCT) initiative that began in 2011 established a conservation area and paid indigenous communities to protect a portion of their territory that is threatened by deforestation. The program was evaluated in 2015 (Giudice et al., 2019).

The CCT introduced cash and in-kind payments (ResoM) in one of the poorest indigenous communities in Peru (Cont), although the threat of deforestation was low (Cont), as was the enforcement capacity of the PES to monitor and sanction non-compliance (ResoM). A professionally guided engagement approach (ResoM) was used to develop investment plans, and communities were compensated conditional on fulfilling monitoring responsibilities (ResoM) led by specific committees. The communities chose to invest the bulk of their payments in agroforestry, a labor-intensive practice, on previously abandoned lands rather than opening new forested areas, revealing that monetary incentives were perceived to be advantageous (ReasM), leading to a small but significant forest conservation (Out). However, spatial targeting decisions (ResoM) coupled with adverse self-selection -i.e., when PES enrolls individuals who would have reached the program outcomes whether or not they participated in the program (Ezzine-De-Blas et al., 2016) (ResoM) ultimately led to low forest conservation effectiveness (Out).

5.2.5. The Socio Bosque program

Ecuador's government-run Socio Bosque program was launched in 2008 with the objective of achieving ecosystem conservation, reducing poverty, plus climate change adaptation and mitigation goals. The program offers a contract-based conservation incentive to voluntary landowners who commit to conserving forests on their properties for 20 years. Up to 2019, Socio Bosque had enrolled >1.6 million hectares of land including ~175,000 beneficiaries and spanning ~15.4% of Ecuador's territory, largely tropical moist forest. The program was evaluated in 2011 (Krause et al., 2013), in 2015 (Jones et al., 2017), and in 2019 (Etchart et al., 2020).

The three Socio Bosque case studies analyzed were implemented in a context of heterogeneous ethnic groups, including indigenous communities and non-indigenous peasant households (campesinos) located close to protected areas with little access to markets, low agricultural productivity, and subsistence-oriented livelihood strategies (Cont). These communities had no formal representation nor preexisting internal forest use rules (Cont). Despite the program's efforts to implement democratic decision-making processes, the engagement approach of the program was top-down (ResoM), with unequal information (ResoM) and participation that exacerbated endogenous power dynamics (Out), in particular related to women and marginalized groups. Combined with the participants' perception of the PES implementation as unfair and a low sense of ownership (ReasM), this resulted in low network ties (Out) and an inequitable distribution of the benefits (Out).

On the other hand, in the context of low agricultural productivity and market isolation (Cont), participants did perceive the monetary benefits as advantageous (ReasM) and enrolled land unsuitable for agriculture. Even though the PES rules were perceived as too strict

(ReasM) in terms of monitoring and sanction enforcement, and parallel policies reinforced land-use restrictions, the pro-environment attitude of the communities and the perceived monetary benefit (ReasM), particularly for older landowners, did reduce deforestation on enrolled land (Out). However, unsustainable funding sources (ResoM) meant payment was suspended for two years between 2015 and 2017. During this period, monitoring and sanctions were maintained to ensure compliance with the long-term contract, triggering a feeling of unfairness and a widespread lack of trust (ReasM). During the suspension, some landowners extended their cultivated agricultural area or increased their production of short-cycle crops, others undertook drainage projects to improve agricultural productivity (Out). Deforestation on both enrolled and non-enrolled properties increased during payment suspension (Out), at lower rates on the former.

5.2.6. The Bolsa Floresta Program (BFP)

The Bolsa Floresta program in Brazil is an integrated set of interventions aimed at rewarding traditional and indigenous people in protected areas for maintaining environmental services through net zero deforestation and sustainable land-use practices, while improving their welfare. The program combines a PES type of initiative based on cash payments combined with in-kind benefits such as income-generating conservation and development projects for the communities, public services, and incentives for collective action. The program was evaluated in 2009 by two studies (Agustsson et al., 2014; Gebara, 2013), then again in 2011 (Börner et al., 2013), and in 2012 (Alves-Pinto et al., 2018).

The five case studies were carried out in subsistence-oriented contexts (Cont), with limited access to markets and basic services (Cont), low-income levels and low deforestation rates at the onset of the PES (Cont). Nonetheless, improvements in infrastructure and environmental education (ResoM) activated non-monetary motivation to enroll and comply (ReasM) and reinforced pro-environment and anti-clearing attitudes (ReasM) (e.g. reporting violations and opposing non-compliers). The combination of the long distance needed to collect the payments (ResoM) in some areas with the perception that payments were insufficient triggered a feeling of non-advantageousness for participants (ReasM). This, combined with reduced access to land in the short-term (Out) and less income from forests (Out) made some participants feel worse off (Out). In other areas, poor families perceived the PES as advantageous (ReasM) due to increased income and work opportunities (Out), revealing a monetary motivation to enroll and comply (ReasM). These contrasting responses are supported by the fact positive forest conservation outcomes were only found in one case study. The lack of clear results on deforestation rates (Out) are due to the weak monitoring system (ResoM) in place, leaving aside the unclear results in terms of forest conservation caused by the overlap of PES and the existing protected area, as well as casting doubt on whether deforestation results are attributable to the PES.

6. A middle-range theory for PES in the Amazon

The middle-range theory we built through this review identifies the conditions in which PES in the Amazon produce positive environmental and social outcomes (Fig. 4).

PES in the Amazon appear to deliver positive livelihood and forest conservation outcomes when they: (a) deliver combined cash and in-kind incentives, (b) develop environmental awareness through capacity building, (c) are designed and implemented through equitable and inclusive engagement of stakeholders in decision making and planning, (d) apply non-discretionary and transparent spatial targeting, (e) guarantee strong conditionality through robust monitoring of compliance, and (f) guarantee stable delivery.

In the Amazonian context, when these resources are carefully introduced and take into account the marked heterogeneity of ethnic groups and their values, the subsistence-oriented livelihood strategies,

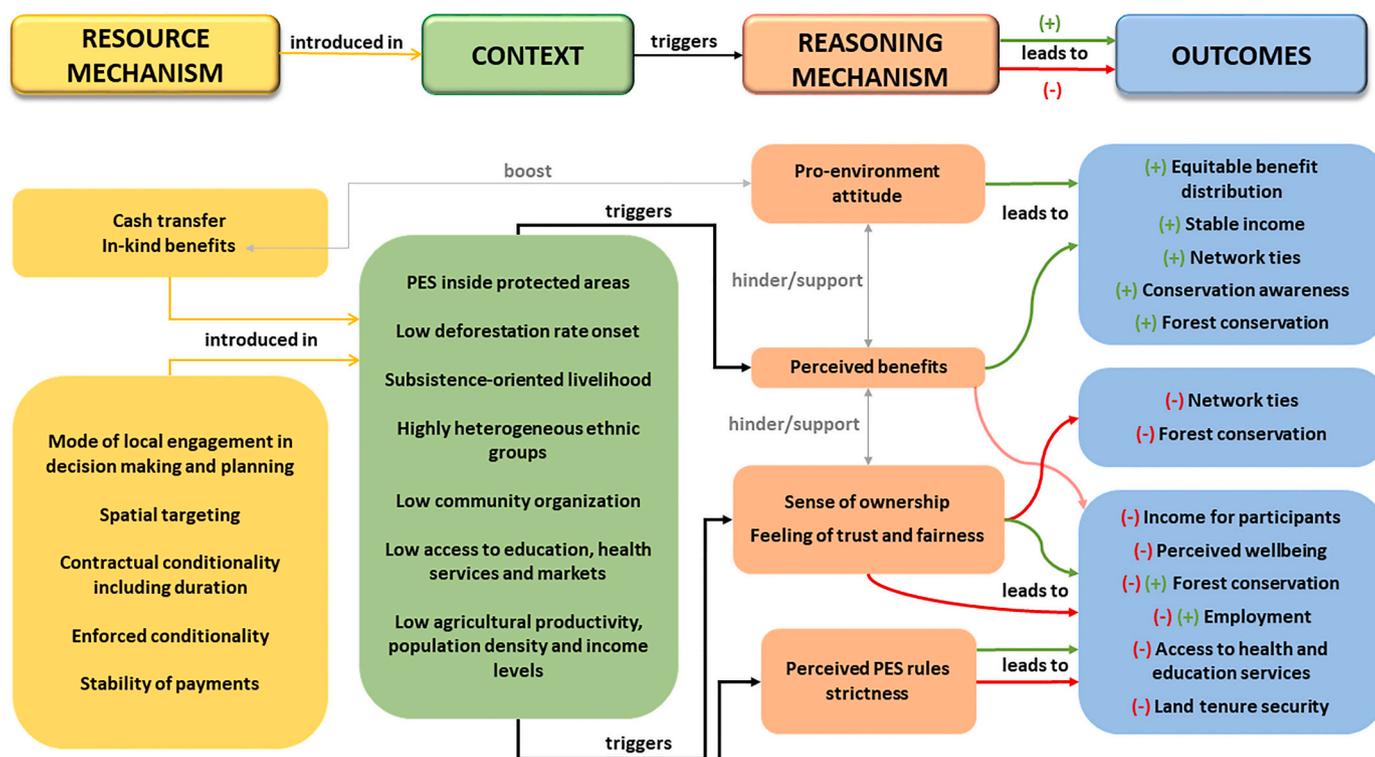


Fig. 4. The middle-range theory of PES in the Amazon. Arrow color coding: Intervention features introduced in a context (yellow arrow). Context characteristics triggering human reasoning (black arrow). Reasoning mechanism leading to positive (green arrow) and negative (red arrow) outcomes. Direct relationship between C-M-O components (grey arrow). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

the difficult access to markets and basic services, and the mostly unorganized local representation and low incomes, they increase conservation awareness and knowledge, strengthen organizational capacity, and stabilize income levels. They can also avoid deforestation and reduce external pressure on forests. Conversely, negative social and environmental outcomes include benefit distribution being perceived as inequitable, increased conflicts that hamper network ties and perceived well-being, and increased deforestation in land not enrolled in PES. PES resources must be introduced while accounting for their interaction with local power dynamics and inequalities to avoid reinforcing them, build trust, a sense of ownership, and a perception of fairness not only among the participants and PES staff, but also among nonparticipants, even when PES rules are perceived as strict. For instance, transparent engagement coupled with technical capacity building can produce a feeling of a better welfare for both participants and nonparticipants.

Additionally, capacity building activities that boost pro-environment attitudes, and carefully delivered payments and in-kind benefits, trigger the perception of both monetary and non-monetary advantages and thus support positive socio-economic and forest conservation outcomes. This is the case of the Bolsa Floresta program in the Juma Sustainable Development Reserve in Brazil, a context of ethnic diversity and low education levels. There, despite a feeling of non-advantageousness among participants, anti-clearing and the pro-environment attitude fostered by technical support introduced by the PES program, increased the level of education and strengthened network ties. In terms of environmental outcomes, external pressure on forests decreased slightly, but this seemed more linked to the creation of the protected area and to enforcement and monitoring rather than to the incentive provided by the PES.

7. Discussion and conclusions

Under which conditions do PES in the Amazon generate changes in behavior and reach the desired livelihood and forest conservation

outcomes? Our results show that discretionary targeting, adverse self-selection, unstable PES payments, and unequal information and participation among socially and ethnically diverse stakeholders, introduced in a context of low-income subsistence-oriented livelihoods, trigger a lack of trust, feelings of unfair implementation, and low sense of ownership, leading to negative forest conservation outcomes. On the other hand, combining payments with in-kind benefits, capacity building and equitable and transparent participation reinforce pro-environment attitudes and trust, motivation to enroll and to comply with PES beyond monetary motives, and produce positive forest conservation outcomes. The size of the sample used for our review may seem small, but this is common in realist syntheses (see for instance Hoffecker, 2021) that require the context, the mechanisms and outcomes all to be present in the papers reviewed. The middle-range theory we draw from this review is an initial theory, sufficiently abstract to provide broad guidance for PES schemes in the Amazon region, and to enable further refinement (Hoffecker, 2021).

First, in contexts of mostly unorganized local representation, unequally informed stakeholders and discretionary spatial targeting often trigger a perception of unfairness of the implementation process of the PES scheme. Coupled with a low sense of ownership and lack of trust, PES in the Amazon can result in weak network ties and low forest conservation. Lack of trust and feelings of unfair implementation have been shown to produce negative outcomes (Miljand et al., 2021). Indeed, inclusive and transparent decisions are crucial for PES success (Hayes et al., 2019). Likewise, giving locals authority over resources creates empowerment (Nilsson et al., 2016) and motivation through autonomy (Akers and Yasué, 2019). As our results confirm, using a transparent process involving workshops and consultations to guarantee empowerment rather than a consultative approach to PES design (Gebara, 2013), engaging unrepresented stakeholders (Sarmiento Barletti et al., 2020), and ample communication (Andersson et al., 2018), enhances this sense of ownership. Earlier reviews (e.g. Hejniewicz et al., 2014; Pritzlaff, 2018) found that trust building through early

stakeholder engagement and transparent communication contribute to successful PES programs. Trust in the capacity of institutions also influences the likelihood of enrolling in PES, hence affecting their success (Athelet et al., 2021; Grosjean and Kontoleon, 2009). As confirmed by our review, building trust is a key process to create legitimacy, a PES-preconditioning factor for its effectiveness (Wunder et al., 2020). We show how addressing heterogeneity of participants and nonparticipants, as well as power dynamics, through transparent negotiation and fostering a sense of ownership and trust triggers positive environmental and social outcomes.

Second, when preexisting pro-environmental attitudes exist, our results show that in-kind benefits (e.g. capacity building, network creation) and inclusive stakeholder engagement reinforce positive attitudes, in turn supporting a sense of ownership, and resulting in positive forest conservation outcomes. Miljand et al. (2021) highlight the fact that interactions between economic and environmental attitudes, which are sometimes opposing, hinder the capacity to establish a dominant causal chain. Nilsson et al. (2016) argue that PES schemes can alter human behavior to achieve conservation outcomes when economic benefits from conservation livelihood are perceived as advantageous, but that this is not always the case. Other authors argue that intrinsic motivations and cultural practices better explain land use behavior than monetary incentives (Muradian et al., 2010). We found that the combination of cash and in-kind payments that provide alternative sources of income triggered perceptions of the advantages of PES. When the economic motive predominates and the incentives are large, these can become embodied in the beneficiaries' future expectations (Montoya-Zumaeta et al., 2019). Indeed, shorter but recurrent and renegotiated contracts might work better, especially in situations of limited trust (Schomers et al., 2015).

Our results emphasize the importance of accounting for social and cultural outcomes of PES (Blundo-Canto et al., 2018; Samii et al., 2014), and show that this is particularly important in socially and ethnically diverse contexts such as those often found in the Amazon region. Our results reinforce the need for PES to develop and account for social and institutional capacities as essential components of an affective intervention (Hejnowicz et al., 2014).

Third, our results underscore the importance of mapping critical contextual factors, such as existing power asymmetries and dynamics, as a key element of PES design, to prevent perceptions of unfairness, unequal benefit distribution and even threats to existing social ties. Gender and capital inequalities need to be addressed in PES design (Sarmiento Barletti et al., 2020). Not reinforcing unequal power relations has been argued to be an underlying condition for the delivery of positive social outcomes, ensuring persistence, equity, and making sure social safeguards can be met (Krause et al., 2013).

Moreover, local community empowerment and equitable sharing of costs and impacts of conservation also appear to underlie positive livelihood and environmental outcomes of PES. Empowering participants and guaranteeing their independence encourages participants to comply with PES rules, even if they are paid (Akers and Yasué, 2019). Indeed, in-kind benefits help landowners maintain conservation practices on their land after payments end (Börner et al., 2017; Dayer et al., 2018; Nilsson et al., 2016).

Fourth, spatial targeting is among the key weaknesses of PES, as stressed by Ezzine-De-Blas et al. (2016). Indeed, we found that PES in the Amazon are often based on discretionary targeting in areas where the threat of deforestation is actually low. In some cases, this triggers adverse self-selection due to the desire to enroll land that is unsuitable for agriculture only to obtain the economic advantage of the payment. Targeting high provisioning or high threat areas to counteract adverse selection biases (Wunder et al., 2020) is crucial to up-scale programs (Giudice et al., 2019), yet are seldom applied.

Finally, suspension of payments due to financial instability triggers feelings of distrust towards PES implementers and of unfairness when sanctions are nevertheless imposed. This may result in negative forest

conservation outcomes as landowners face difficulty maintaining conservation behavior (Etchart et al., 2020). To mitigate such effects, Wunder et al. (2020) refers to institutional inputs needed to launch the program. Starting the payments after community agreements are established and plans certified, appears to be a successful strategy. Putting pressure on donors to support longer-term investments has also been proposed (Sarmiento Barletti et al., 2020). Strong conditionality and payments can be renegotiated, but this has to be done transparently. Relaxing any of the resource mechanisms would lead to lower environmental or social outcomes.

8. Risk of bias and limitations of the study

None of the case studies we analyzed were presented by their authors using a realist evaluation framework, thus there is a risk of interpretation bias in defining the context, mechanisms and outcomes. To mitigate this risk, the context, mechanism-resource, and outcomes in each paper were classified based on the factual elements presented in the papers. We systematically reexamined the initially proposed analysis grid based on the literature using the dimensions, variables, and modalities found in the reviewed papers, alternating checks between co-authors of the present study also aimed at minimizing bias.

Reasoning mechanisms, rarely made explicit in the papers, were drawn from sentences that explained motives, fear, threat appraisal, and values. We applied concepts from behavioral theories used in environmental conservation interventions (Miljand et al., 2021; Simmons et al., 2020, 2021) to identify reasoning variables and modalities. All reasoning mechanisms were coded based on explicit findings in the studies reviewed or when the reasoning was obvious even though not formulated in those terms. The code report is provided in S4.

Defining mechanisms along with the boundaries between mechanisms and context, or mechanisms and outcomes, are common challenges in realist evaluations (Greenhalgh and Manzano, 2021; Lemire et al., 2020). Back and forth cross-checks between the co-authors allowed us to produce a robust analysis grid.

9. Recommendations for future research

Our review demonstrates the importance of studying interactions between the resources a PES program introduces in a given context and the behavioral outcomes associated with the reasoning of the individuals and communities who interact with these resources and contexts, in order to achieve more informed and effective design and implementation. As most of the evidence provided in conservation programs fails to present a causal model to underlie mechanisms that connect intervention and human well-being outcomes (Cheng et al., 2020), this limited the size of our sample. Future research focused on evaluating causal processes leading to conservation, will clarify relationships between heterogeneous contexts, interventions, outcomes, and impacts, and enable progress towards evidence-informed conservation practice and policy design. Future research will also advance our understanding of the underlying factors required to achieve forest conservation in the Amazon and elsewhere, and develop reference causal models for PES design, adaptive management and evaluation (Blundo-Canto et al., 2018; Cheng et al., 2020). Systematization, monitoring and evaluation research embedded in program implementation would make it possible to fill these data gaps and to undertake more complete assessments of the mechanisms through which PES produce outcomes. Similarly, a more transparent presentation of the actual rules of PES, including sanction mechanisms, would enable better assessments of additionality. The papers analyzed in this study seldom discussed sanction mechanisms and only partially addressed deforestation outcomes, thus, evidence of additionality remains inconclusive. Analyzing PES using a realist framework highlights the heterogeneous Context-Mechanism-Outcome configurations that explain how, why, for whom, and under what conditions these incentives can achieve forest

conservation. By considering human reasoning and responses that the PES can activate in a given context, such analyses will support PES designers and help implementers steer their actions so as to achieve the desired outcomes. Future research should focus on behavioral aspects (e.g. attitudes, motives, threats, norms, trust), better integrating behavioral theories in PES theory to understand why PES succeeds or fails. Given the impact of trust and power dynamics on ecological outcomes (Pascual et al., 2014), future PES research should focus on acquiring in-depth understanding of contextual factors for PES design and implementation, in particular power imbalances, information asymmetries and heterogeneity between participants and nonparticipants, and their pre-existing attitudes towards conservation.

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ecolecon.2022.107697>.

Author contributions

F.E.M.d.O.: Conceptualization, Investigation, Methodology, Data curation, Formal analysis, Software, Interpretation, Writing – original draft, review & editing.

G.B.C.: Conceptualization, Investigation, Methodology, Data curation, Interpretation, Validation, Supervision, Writing - review & editing.

D.E.d.B.: Conceptualization, Writing - review & editing.

Disclosure statement

The authors are not aware of any affiliations, memberships, funding, or financial holdings that might be perceived as affecting the objectivity of this review.

Funding

This work was publicly funded through ANR (the French National Research Agency) as part of the “*Investissements d’avenir*” program under the reference ANR-16-IDEX-0006. This study is the result of the first author’s master thesis, who was recipient of the Erasmus+ Programme of the European Union (Higher Education - Erasmus Mundus Joint Master Degrees: nr. 2016–2051/001–001-EMJMD) scholarship, which fully funded the double master’s degree program in the European Forestry (University of Eastern Finland/AgroParisTech-Université de Lorraine Nancy). The preparation of this manuscript continued during the first author’s research position at the University of Freiburg. The submission of this article was approved by all the authors and the funding sources were not involved.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We are grateful to the anonymous reviewers, whose equally constructive and challenging comments have strengthened this paper.

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