

Payments for ecosystem services in the tropics: a closer look at effectiveness and equity

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We undertake a review of academic literature that examines the effectiveness and equity-related performance of PES initiatives targeting biodiversity conservation in tropical and sub-tropical countries. We investigate the key features of such analyses as regards their analytical and methodological approach and we identify emerging lessons from PES practice, leading to a new suggested research agenda. Our results indicate that analyses of PES effectiveness have to date focused on either ecosystem service provision or habitat proxies, with only half of them making explicit assessment of additionality and most describing that payments have been beneficial for land cover and biodiversity. Studies evaluating the impact of PES on livelihoods suggest more negative outcomes, with an uneven treatment of the procedural and distributive considerations of scheme design and payment distribution, and a large heterogeneity of evaluative frameworks. We propose an agenda for future PES research based on the emerging interest in assessing environmental outcomes more rigorously and documenting social impacts in a more comparative and contextually situated form.

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Introduction

Payments for Environmental or Ecosystem Services (PES) have become a means to promote biodiversity conservation and rural development, particularly in tropical and sub-tropical regions [1]. National or regional PES programs are currently implemented in countries like Costa Rica, Mexico, Ecuador, Vietnam, China, South Africa or the United States, while smaller regional programs have been tested in European countries like Germany and the UK [2]. Small-scale PES projects promoted by non-governmental organizations to enhance watershed protection and biodiversity conservation, as well as to protect carbon reservoirs and sinks under the umbrella of the United Nations Framework Convention on Climate Change — as carbon offset and REDD+ projects — have also been developed worldwide [3]. These programs and projects have usually become part of a conservation policy mix, in which the direct incentives provided by PES co-exist with more traditional regulatory conservation approaches [4].

Research examining the performance of PES schemes has increased exponentially over the past decade. Academic PES reviews to date have focused on a few programs and projects [5], have had a single topical or geographical focus [6–11], or have relied mostly on qualitative information provided by project managers and conservation organizations [12]. These analyses have sought to distill lessons on what PES schemes have achieved in environmental and livelihood terms, to explain these achievements, and to analyze what could be done to improve design and performance.

Our review aims at a better understanding of conservation interventions but is distinctive from existing reviews in at least three ways. First, we focus only on peer-reviewed publications analyzing ongoing — not planned or potential — PES initiatives implemented in tropical and sub-tropical countries across Asia, Africa and Latin America. These regions contain the highest concentrations of biodiversity on the planet and are experiencing rapid change that is leading to the loss of biodiversity [13,14]. These regions also contain deep, multifaceted poverty [15] where the burden of ecosystem protection is often borne by those least able to afford it [16]. Second, we are principally interested in understanding if researchers have considered PES schemes to be *effective* both in achieving their biodiversity and environment-related goals, that is, if they have achieved the goals set by the

correspondent PES program or project, and to be *efficient* in their use of financial resources, given that PES have often been praised as cost-effective alternatives compared to more conventional conservation instruments [17,18]. Finally, we are interested in highlighting if researchers have considered PES schemes to be *equitable*, that is, if they have involved poor people in their design and implementation and if they have benefited participants equally. Therefore our objective is not to judge by ourselves if the PES cases reviewed are effective, efficient and equitable but instead to annotate what the reviewed article authors consider such cases to be.

We also acknowledge that the equity judgments of the authors in the reviewed articles can be considered less 'objective' than effectiveness results, since such judgments may depend on the scholars' approach to the concept and the potential for conflict between her views and those of local people. However, we think that some aspects of equity, for example the distribution of jobs or income derived from PES implementation, can indeed be measurable and thus presented with objective data, while other equity-related criteria might be more prone to subjectivity, such as the existence of conflicts or participation levels in PES design and implementation.

Nonetheless, we believe that all aspects deserve attention given that PES is part of a broader international environmental governance agenda that aims to transform the distribution of rights and responsibilities in resource management across the world, and particularly in the global South [19]. An equity focus is thus important to understand if PES could serve as a means of redistributing the costs and benefits of conservation in a way that alleviates poverty and minimizes social conflict [20,21**]. Finally, throughout our analysis, we investigate the methods employed by scholars to draw conclusions on economic and ecological effectiveness and equity and examine if methods and the outcomes described are related to each other.

Overall, the findings and the resulting discussion contribute toward establishing an agenda for future PES research by identifying data and analytical gaps, and pointing to the opportunities and challenges lying ahead to develop more robust research approaches. The results are also relevant for PES practitioners to the extent we offer an overview of existing PES schemes in sub-tropical and tropical countries, and we call for partnerships to better design and monitor PES worldwide.

Methods

We compiled a database of peer-reviewed literature in Scopus for articles published between January 2003 — the year of the publication of the first Millennium Ecosystem Assessment Report — and December 2013, searching for the terms 'payment for environmental

services' or 'payment for ecosystem services' and 'conservation' anywhere in title, abstract or keywords, and the term 'tropical' anywhere in the text. The results returned 213 ('environmental') and 200 ('ecosystem') articles, of which over 80% had been published between 2009 and 2013, indicating the growing popularity of the subject and the increase in scholarly attention to PES.

We targeted journal contributions that (i) analyzed one or more implemented PES initiatives in tropical or sub-tropical countries, excluding Australia for being a highly developed country and China because half the country falls outside the sub-tropics; (ii) focused on initiatives with direct or indirect biodiversity conservation objectives, that is, they targeted the conservation or restoration of an ecosystem, or the provision of related ecosystem service(s), and (iii) examined PES effectiveness and/or equity considerations, such as the degree to which environmental objectives have been achieved, people's access to project activities, participation in design and implementation, and the impact and distribution of incentives. We excluded articles developing a conceptual framework, argument or model related to PES theory, practice or the targeting of payments [4,22–30]; focusing on analytical issues unrelated to effectiveness and equity, such as motivations to participate in PES [31–33]; and those that did not include a purposive analysis of case studies, such as summary articles in special issues, the above mentioned PES reviews, and articles with anecdotal evidence on PES implementation to illustrate a related argument [34–37].

Our final database includes 34 articles focused on 29 PES programs and projects (Table 1). The World Bank's sponsored RISEMP project has been implemented in different countries and we have considered each country scheme as a separate case study. Thirty articles examine only one PES initiative [38–47,48**,49–54,55**,56,57**,58–66,67**], one paper focuses on two cases [68], and three analyze three or more schemes in the same article [69–71]. From each of these contributions, we extracted the following information to provide some background on the location and typology of the PES schemes analyzed: location of the researched PES scheme (continent, country), scheme reach (national, local), type of service being paid for (well-defined ecosystem service, proxy), and type of land tenure where it has been implemented (private, public, communal). We also recorded each article's authors, year of publication, the PES scheme analyzed, the location of the scheme the article is focusing on, the author(s)' analytical objective(s), methods, the characterization of effectiveness and/or equity by the author(s), and PES outcomes reported. For the latter, and to reduce potential bias in article assessment, we extracted the relevant text in which the authors explicitly referred to effectiveness, perceived level of *additionality* — i.e. the extent to

Table 1**Some key characteristics of the reviewed PES schemes.**

Region	Country	PES scheme	PES scale	PES developer	Activities paid for and link with desired services – (Direct or Proxy)*	Type of tenure	Article(s) # in reference list
Asia	Cambodia	Eco-tourism payments scheme	Local	NGO	Villagers may not hunt key species and must abide by a land use plan. Revenue received from tourist visits used to support plan overseeing and enforcement – (P for biodiversity conservation)	Private	[71]
Asia	Cambodia	Agri-environment payments scheme	Local	NGO	Offers preferential prices to rice farmers (wildlife friendly certification) in exchange for abiding by the land-use plan and no-hunting rules – (P for biodiversity conservation)	Undefined	[71]
Asia	Cambodia	Nest conservation direct payments scheme	Local	NGO	Farmers paid directly against number of nests protected from poaching – (D for bird biodiversity protection)	Communal	[71]
Asia	Cambodia	NGO-driven community-based payments scheme	Local	NGO	Communities are <i>ex ante</i> incentivized to develop local institutions (committees and land-use plans) to stop deforestation in the buffer zone of a protected area (P for biodiversity conservation)	Communal	[65]
Central America	Mexico	National program of payments for hydrological services	National	Federal government	Farmers and communities receive payments to conserve forests through the development of monitoring and patrolling activities – (P for watershed regulation)	Communal, Private	[54,63,67**]
Central America	Mexico	PES carbon forestry national program scheme	National	Federal government	Farmers and communities are paid for forest conservation or reforestation activities – (D for carbon sequestration)	Communal, Private	[46]
Central America	Mexico	Fondo Bioclimatico carbon project scheme	Local	NGO	Farmers and communities are paid for forest conservation or reforestation activities – (D for carbon sequestration)	Communal, Private	[62,69]
Central America	Mexico	Coatepec watershed payments sub-national scheme	Local	Sub-national government (state, municipality)	Farmers are paid for forest conservation or reforestation activities – (P for watershed regulation)	Private	[53]
Central America	Mexico	Monarch Butterfly Fund payments scheme	Local	NGO	Farmers and communities are paid for forest conservation, including monitoring and enforcement activities – (P for biodiversity conservation)	Communal, Private	[47,48**]
Central America	Costa Rica	PES national program scheme	National	Federal government	Farmers are paid for forest conservation – (P for watershed regulation and biodiversity conservation)	Private	[39,43,44, 55**,61]
Central America	Costa Rica	RISEMP project scheme	Local	Multilateral organization (World Bank)	Farmers are paid to develop agro-forestry sustainable practices – (P for biodiversity conservation and carbon sequestration)	Private	[38,41,56]
Central America	Costa Rica	Heredia watershed payments scheme	Local	Sub-national government (state, municipality)	Farmers are paid to convert agricultural land into forests – (P for watershed regulation)	Private	[70]

Table 1 (Continued)

Region	Country	PES scheme	PES scale	PES developer	Activities paid for and link with desired services – (Direct or Proxy) ^a	Type of tenure	Article(s) # in reference list
Central America	Nicaragua	RISEMP project scheme	Local	Multilateral organization (World Bank)	Farmers are paid to develop silvopastoral management practices – (P for biodiversity conservation and carbon sequestration)	Private	[38,40,49]
Central America	Nicaragua	San Pedro del Norte watershed payments scheme	Local	Sub-national government (state, municipality)	Farmers are paid to convert agricultural land into forests – (P for watershed regulation)	Private	[70]
Central America	Guatemala	Las Escobas watershed payments scheme	Local	NGO	Enforced conservation and adoption of SFM and sustainable agricultural practices by protected area inhabitants – (P for biodiversity conservation and watershed regulation)	Public (held in trust by NGO)	[69]
Central America	Belize	Rio Bravo carbon project scheme	Local	NGO	Forest conservation against a deforestation and degradation baseline scenario – (D for carbon emissions avoided)	Public (held in trust by NGO)	[69]
Central America	Honduras	Jesus de Otoro watershed payments scheme	Local	Sub-national government (state, municipality)	Farmers are paid to convert agricultural lands into forests and develop organic agriculture – (P for water regulation)	Private	[70]
South America	Bolivia	Los Negros watershed payments scheme	Local	NGO	Farmers are paid for avoiding forest conversion into agriculture – (P for water regulation and biodiversity conservation)	Private	[42]
South America	Bolivia	Noel Kempff climate action project scheme	Local	NGO	Forest conservation against a deforestation and degradation baseline scenario – (D for carbon emissions avoided)	Undefined	[68]
South America	Colombia	RISEMP project scheme	Local	Multilateral organization (World Bank)	Farmers are paid to develop silvopastoral management practices – (P for biodiversity conservation and carbon sequestration)	Private	[38]
South America	Colombia	Oak biological corridor payments scheme	Local	NGO	Farmers are paid per hectare to promote forest conservation by switching to more sustainable silvopastoral pasture management practices that would increase milk production and maintain the remaining forests – (P for biodiversity conservation)	Private	[58]
South America	Brazil	Bolsa Floresta payments program scheme	Sub-national	Sub-national government (state, municipality)	Households are paid a monthly fee (regardless of environmental additionality level) to reduce conversion of primary forests on their lands, with additional support provided for income-generating activities that do not rely on deforestation – (P for biodiversity conservation)	Communal, Private	[60,68]
South America	Ecuador	Socio Bosque payments program scheme	National	Federal government	Farmers or communities are paid a biannual fee related to the size of their forests to be protected. They commit to avoid land-use change, hunting for commercial purposes and to report third party invasions – (P for biodiversity conservation and watershed regulation)	Communal, Private	[64,66]

Table 1 (Continued)

Region	Country	PES scheme	PES scale	PES developer	Activities paid for and link with desired services – (Direct or Proxy) [*]	Type of tenure	Article(s) # in reference list
Central Africa	Rwanda	Nyungwe national park payments scheme	Local	NGO	Households are paid to refrain from illicitly collecting forest products – (P for biodiversity conservation)	Undefined	[57**]
Southern Africa	Madagascar	Mantandia PES project scheme	Local	NGO	Farmers are paid to reduce land-use change and to develop forestation activities – (P for biodiversity conservation and carbon sequestration)	Public	[50]
Southern Africa	Tanzania	Uluguru mountains watershed payments scheme	Local	NGO	Farmers are paid to implement and maintain a set of specified soil conservation measures, such as agro-forestry, reforestation, grass strip planting and terrace development – (P for watershed regulation)	Private	[59]
Southern Africa	South Africa	Working for Water payments program	National	Federal government	External contractors employing farmers and communities are paid to remove alien vegetation species to reduce the presence of invasive plants on country's scarce water resources – (P for watershed regulation and biodiversity conservation)	Undefined	[45]
Southern Africa	Namibia	Community-based NRM payments program	National	Federal government	Farmers and communities receive a share of benefits from photographic safaris and trophy hunting, as well as they are incentivized for protecting wildlife and other natural resources – (P for wildlife conservation)	Communal	[52]
Southern Africa	Mozambique	Nhambita carbon project scheme	Local	NGO	Farmers are paid to plant trees on the farm (boundaries or in mixed rows along with crops) – (D for carbon sequestration levels by planted species)	Undefined	[51]

^{*} We indicate here the activity for which targeted landowners are paid for, and we note if payments are directly related to the measurement of the desired ecosystem services.

which payments result in environmental outcomes that would not have occurred otherwise-, cost-effectiveness, equity, existence of conflicts and perceived legitimacy. Such text was then summarized for explanatory purposes — appearing as ‘Outcome explained’ data in Supplementary Tables 1 and 2.

PES for biodiversity conservation in tropical and sub-tropical regions

Location and typology of PES schemes

Table 1 shows that the 29 PES schemes examined are not evenly distributed across tropical and sub-tropical regions but concentrated in Central and South America, and less in sub-Saharan Africa. Mexico, Cambodia and Costa Rica have the highest number of PES schemes, with all schemes present in Cambodia being designed by NGOs and developed at local scales. The Costa Rican PES national program is analyzed in seven articles, Mexico's national watershed payments program in four articles and

the World Bank's silvopastoral RISEMP project in three. Consistent with other reviews [8,11], most PES schemes have been designed and promoted by NGOs that, in most cases, have received seed financial support from international donors. National (6) or sub-national governments, including states and municipalities (5), have promoted eleven of the 29 PES schemes in our database. Logically, national governments have supported schemes of national reach, while sub-national and local governments have promoted schemes affecting areas within their administrative boundaries, for example, the Bolsa Floresta scheme promoted by the Brazilian Amazonas state government [60,68] or the watershed payment scheme in the Mexican municipality of Coatepec [53].

Most analyses report that schemes reward landowners against the provision of land-use activities that constitute a proxy of the desired ecosystem services. The exception are project schemes linked to voluntary carbon markets

(e.g. Belize, Mexico), which need to monitor and accurately quantify carbon to participate in such markets [46,51,62,68,69], or niche-based initiatives concentrating on very particular services, such as bird nest protection against poaching [71]. Tenure conditions underlying each PES scheme differ across countries and according to local realities. In Mexico, for example, national and local schemes supporting forest conservation and management — to provide carbon and watershed services — target lands under communal and private property as most forests are administered by communities who hold these in common or have divided up their lands across households. This is also the case of programs with the same or complementary objectives (biodiversity conservation) in Brazil and Ecuador. This contrasts with the Costa Rican case, where forests are generally owned privately and payments strictly channeled to individual landowners.

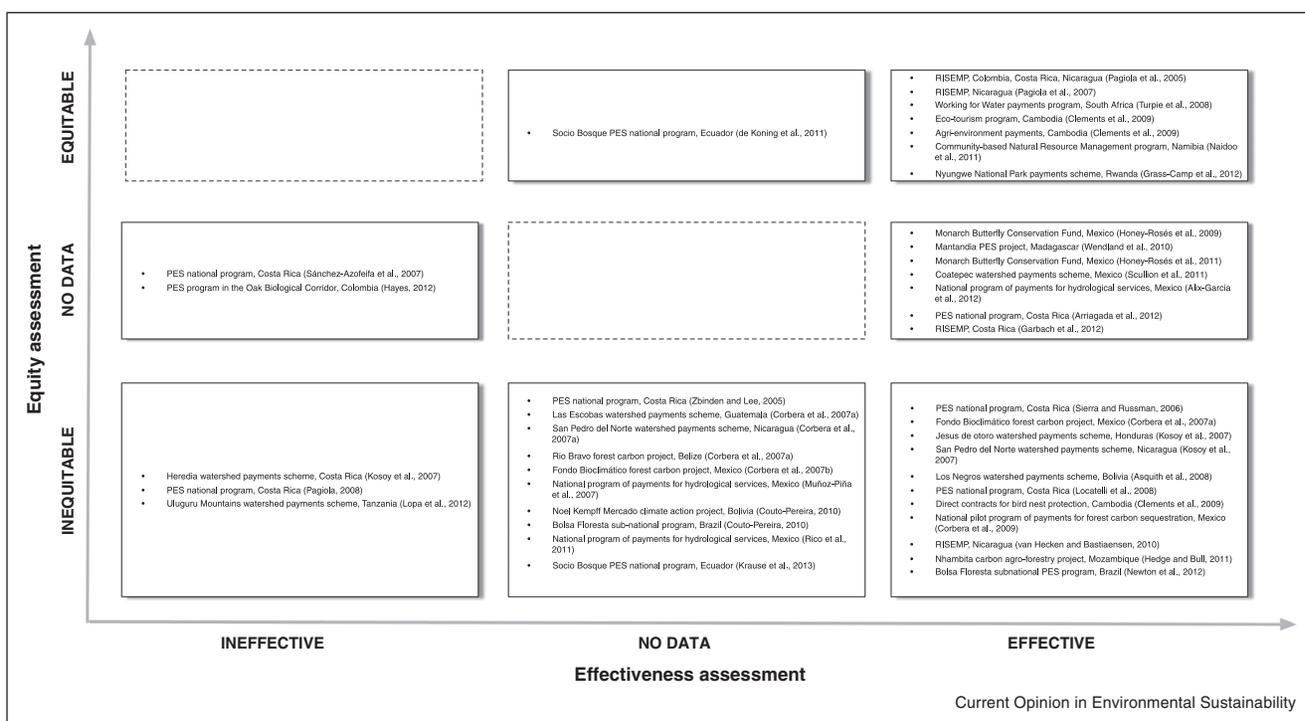
PES schemes with a strong focus on sustainable agricultural practices or agro-forestry as a proxy for biodiversity conservation or watershed regulation target private, household-managed lands in order to link practices, outcomes and payments more directly [38,40,42,51,58,59,62,70]. When PES schemes are developed on public lands, NGOs manage targeted lands in trust or operate jointly with the government in the design and implementation of the scheme [69]. In this regard, payment recipients can include communities and households living within a protected area (e.g. the cases of Cambodia and

Guatemala) or the NGO alone (e.g. the case of Belize). It is worth highlighting that six articles in our database did not specify the underlying tenure conditions of the PES scheme and we were only able to infer those in one of the six cases because the correspondent scheme (i.e. Costa Rica’s PES national program) had been described extensively in other contributions.

Effectiveness

Figure 1 (see Supplementary Table 1 for extended information) includes 26 articles analyzing the effectiveness of 24 different PES schemes. However, the figure has 30 analytical observations (# bullet points) because some articles examine more than one PES scheme. The variable chosen to infer effectiveness and the methods for data collection vary across case studies. Scholars analyze PES effectiveness in terms of (i) changes in the level of ecosystem service provision, that is, if the service targeted increases or decreases; (ii) changes in land-use or habitat provision, that is, if payments maintain or expand the type of land-use or habitat that is used as a proxy of ecosystem service delivery; or (iii) the combination of both variables. Studies focused on service provision levels rely on perceptions of PES actors and/or secondary data provided by project managers, ongoing field monitoring of biodiversity and ecosystem services in PES areas over time [52,71], and the spatial overlap of PES areas with landscapes providing critical ecosystem services [50] to infer effectiveness. Authors concerned with changes in land use

Figure 1



The reviewed articles classified according to their effectiveness and equity outcomes.

rely on GIS data, including ground-truthing [45] and econometric modeling, such as matching or difference-in-difference regressions [39,41,47,48**,53,55**], actor perceptions and behavioral change [43,57**], and secondary project data [44]. Authors concerned with both dimensions draw on indices to monitor changes in service provision and habitat quality across different types of land uses [40,49,71,72,42], as well as on GIS and biophysical monitoring of service delivery [59].

Within the PES schemes that have been judged as effective, there are both government-led programs implemented at national scale [39,43,45,52,54,55**,60,70] and small-scale initiatives, driven by NGOs and other donors [40,46,47,48**,49–51,53,56,57**,58,69,71,72,42]. Cases described as non-effective also include a variety of typologies and implementation scales [41,44,59,60,70]. Only seven studies have used control groups of non-PES targeted areas or non-participants to account for confounding factors, such as biophysical, socio-economic, political or institutional factors that may be influencing PES performance [39,41,47,48**,51,53,54,55**].

Costa Rica's national PES scheme has been described by some as effective [39,55**] and by others as ineffective [41], depending on the selected geographical region and the methods employed. The success of PES cases in environmental terms has been related to ecological conditions, for example, a strong linkage between PES activities and ecosystem service delivery [45,42], but mostly to scheme design and its interplay with the socio-ecological context. The latter include PES activities that did not induce a loss of income, but instead worked as an upfront incentive for participants to do what PES activities required (independently if they had planned to do such activities anyway) [39,40,43,45,51,71]; partnered with local and/or external organizations to provide technical support and reduce transaction costs [43,71]; induced local behavioral change and led to practices that diminished resource use, or halted land-use change [57**,71]; and did not involve a major departure from existing land-use management and cultural practices [40,53]. Some scholars highlight the importance of providing long-term and periodically adjusted payments to balance participants' changing opportunity and transaction costs over time [40,49], as well as preventing PES implementation in areas with unclear tenure situations or weakly enforced property rights [47,48**,53].

Not all articles concerned with effectiveness refer explicitly to additionality and those referring to it include both effective and non-effective PES schemes. PES schemes have been judged additional when it has been considered that the desired land-use management activities or expected service delivery would not have been implemented or achieved without PES incentives [48**,50,52,54,58]. PES schemes have been judged as

non-additional by the correspondent authors when PES activities have concentrated on land-use areas with low or zero risk of deforestation [39,41,72], and two of these cases have been also — and counter-intuitively — considered effective on the grounds that payments have contributed to maintain forest cover (despite a low level of additionality) [37,71]. Some authors highlight the difficulty of assessing PES additionality based on project design and existing data [53] or of attributing changes in land use or service flows to PES incentives [59]. Only two of the articles included in our sample consider the PES case efficient, understood as a reduction over time of the total costs per unit of service delivery or habitat provision of the given PES initiative [55**,71]. Four articles refer to efficiency only vaguely, considering the PES program inefficient if non-additional [39,41], or indicating how the PES initiative could reduce administrative expenses or increase funding levels in the future to become less costly per unit of PES service or targeted area [50,61].

Equity

Figure 1 above (see Supplementary Table 2 for extended information) includes 24 articles examining the equity outcomes of 24 different PES schemes, with 32 analytical observations (# bullet points). We classified the author(s)' analytical approach to equity following a three-tiered framework: (a) *equity in access*, if the author(s) examined local people's ability to participate in the PES program; (b) *equity in decision-making*, if the author(s) analyzed participants' perceived fairness in project decision-making procedures; and (c) *equity in outcome*, if the author(s) focused on the impact and distribution of project outcomes, including income, across participants [62,69].

As noted in the introduction, we recognize that the equity dimensions of PES design and implementation are prone to subjective analysis, since they rely on the scholar(s)' own interpretation of who is legitimately entitled to participate in a given scheme and who has been left out, or through local people's own perspective of what is fair. But some equity aspects can also be analyzed objectively, for example measuring changes in relative income, or participation rates and voting procedures in meetings. For this reason it is important to be precise about the methods, data and the indicators used to infer the direction of such outcomes and, for this purpose, we have distinguished between studies relying on quantitative data (e.g. minutes of PES meetings, participation and income data from household surveys) from studies based on qualitative interviews and personal observations.

Authors looking exclusively at equity in access mostly rely on informal interviews [39], program and project secondary data [40,63], and only one on household and village surveys [51]. Those concerned with equity in outcome use interviews, focus groups and/or secondary data [49,57**,70], multi-criteria analysis [43], or only

program and project secondary data [44,71]. Analyses that combine these two dimensions and/or also look at equity in decision-making rely on qualitative research methods and/or secondary data [45,46,52,59,62,65,69,71,42], surveys, regressions and/or inequality indices [60,61, 67**,66]. One can observe that there are only five studies that rely on quantitative data from surveys to draw lessons about access, decision-making and outcome. This does not invalidate the findings of the majority of equity-related studies but suggests that there is ample scope for developing more quantitative approaches to provide complementary ‘measures’ of equity outcomes. Seemingly, only six of the articles focused on equity aspects pay attention to decision-making during the design and implementation phase of PES schemes and explain who has been included and/or excluded in such processes. Among these, only two draw attention to unequal bargaining power in PES design [46,62], while none finds evidence of rent seeking by powerful actors, in contrast to literature expectations [73*].

PES schemes considered equitable as well as environmentally effective encompass national PES programs [45,52,64], and donor or NGO-driven schemes [40,57**,71]. PES schemes considered unfair in one or more equity dimensions can be considered either effective [39,43,46,49,51,69–71,42] or ineffective [44,59,70], but many have not been judged in this regard [61–63,67**,68,69,66]. Social conflict has been reported in nine PES schemes [43,46,62,67**,68–70,66]. Some PES activities are reported to have encouraged and ensured the participation of poor and non-poor households in their design and implementation [40]; pursued gender equity [45,52]; empowered local communities through devolved rights in resource management [52]; and have led to a fair distribution of material and/or non-material outcomes across communities and individuals [52,57**,71].

By contrast, other PES schemes have widened the local income wealth gap, often unintentionally and as a result of unfavorable local tenure and political conditions [44,62,69], such as in Mexico’s PES program where formal land right-holders have controlled access to payments at village level and have tended to distribute less to non-right-holders [46,67**], or in Tanzania where the poorest households do not have enough land to dedicate to PES activities [59]. As already noted above, both ‘poor’ and ‘rich’ households’ participation in PES schemes has to do with actual or perceived costs of enrolment, cultural suitability of practices and the latter’s fit with local environmental discourses [49,62,67**]. Some of the scholars’ proposals to address PES schemes’ underperformance in procedural and distributional terms include further incentivizing poor landowners or the landless, who often experience higher opportunity and transaction costs, and providing them with additional external support [43]; supporting transparent and wide benefit sharing by community-based institutions [67**,71], guaranteeing

tenure security for the landless and non-formal right-holders; and improving the value chains of related markets, particularly sustainably harvested timber, so as to increase livelihood gains [43].

Renewing the PES research agenda

Our review confirms that PES implementation in the (sub-)tropics encompass distinct implementation approaches that diverge in conservation goals, scale of implementation and funding approaches. Related research captures the heterogeneity of PES schemes that has been widely noted and referred to in existing literature and reviews [5*,74,75]. The size of our database did not allow for any relevant statistical inference to test any likely relationship between the types of PES analyzed, the scale of implementation, the targeted tenure system and the scheme’s performance in environmental and equity terms. However, we can conclude that scholars report, on average, more positive environmental outcomes in PES schemes than they report positive outcomes in terms of equity. Spatial and/or econometric assessments related to effectiveness are more able to provide insights on the relative level of environmental additionality of PES schemes, that is, being able to compare PES participants’ and non-PES participants’ environmental performance controlling for independent variables and confounding factors [47,48**,51,53,55**]. By contrast, qualitative research seems more able to provide insights on equity, with a majority of schemes being judged unfair at procedural and/or distributive levels.

Positive reporting on equity is mostly based on secondary and project management data — columns 7 and 8 of Supplementary Table 2 — (except for Ref. [57**]), while negative reporting often relies on more extensive fieldwork and primary data collection (except for Refs. [39,44,63,71,42]). The size of our database does not allow us to categorically affirm that more independent and lengthy engagement in the field reveals equity-related challenges more effectively. However, it enables us to confirm that equity-related evidence is better captured through qualitative analyses derived from interviews and focus groups; very few scholars are able to quantify aspects of equity, such as the impact of PES payments on income inequality.

We have noted above a set of context-dependent (including local ecologies) and scheme design and implementation conditions that are conducive to, or impede the realization of positive effectiveness and equity effects. Regarding the first set of conditions, effectiveness and equity are more likely to be realized when PES land management activities fit with locally known management practices and resource use culture and if they fit with the mandate of local resource management institutions, particularly if PES involves social collectives (e.g. a community). Context-dependent conditions include land

tenure relations, mediated by local governance institutions, and the extent to which the latter determine who can get involved in the PES scheme, and who can benefit and by how much. Additionally, local opportunity costs determine the extent to which the payment is attractive to land users — leading to increased effectiveness when payments exceed such value-, as well as the time horizon during which payments are delivered — with effectiveness and equity increasing the longer payments are disbursed. As for scheme design, key aspects to foster performance across the two dimensions include long-term involvement of PES promoters with local recipients, in order to provide the necessary knowledge and expertise, as well as promoters' ability to adapt the PES project as tenure relations and land management costs change over time.

Our review also demonstrates that analyses of effectiveness and equity in PES schemes of tropical and sub-tropical regions have not paid attention to economic costs data, such as the opportunity cost of alternative land use activities, or the transaction costs of program management and monitoring [5[•]]. This is surprising given that effectiveness would need to be related to actual land management costs in order to find out the level of cost-effectiveness and to draw insights on PES efficiency over time. The lack of studies on PES cost-effectiveness has been explained by the fact that most schemes in the global South lack clear metrics to quantify the ecosystem services being delivered, and thus the corresponding associated costs. Those schemes focused on carbon are the most notable exception [76]. However, we argue that, while cost constraints are important, lack of reflection as regards cost-effectiveness is also related to insufficient attention to the issue and the common inability of researchers to access data on opportunity costs, and project start-up, transaction and running costs.

The fact that the methodological approaches chosen by scholars to investigate PES performance in terms of environmental effectiveness and social equity differ broadly, responds to the variety of research budgets available and the scientific schools interested in understanding this conservation tool, which range from land-use scientists to economists, anthropologists and critical geographers. However, we think that future PES research would benefit from some level of analytical integration and coordinated research effort to holistically understand the environmental and social outcomes that PES could generate if well targeted and fairly implemented by practitioners. In doing so, scientific research could be more helpful in providing sound and more coherent evidence to PES implementing actors, governments and both donors and service 'buyers'.

The relationship between effectiveness and equity in PES has already been theorized [21^{••},77] but our review

Box 1 Elements of a future PES research strategy — Activity (A) and Goal (G)

Practitioner-informed meta-analysis of PES

- (A) to develop a global comparative analysis of case studies with inputs provided by PES managers and knowledgeable researchers
- (G) to draw relevant and shared insights on PES design and implementation

Larger and more cooperative research projects

- (A) to generate analyses of PES implementation informed by panel data, in cooperation with practitioners and based on long-term funding and cooperation
- (G) to identify PES impacts on environmental and social conditions, controlling for confounding factors; and to investigate interactions between incentives, individual and collective behavior, wellbeing and local institutions

Multiple methods, data & outcome variables

- (A) to deploy multi-method, and multi-disciplinary evaluative frameworks
- (G) to combine insights from different research techniques to draw a complete understanding of PES effects on local and regional ecologies, as well as on socio-economic and institutional conditions

suggests that there is still a weak link between the two dimensions in empirical studies. This is reflected in the central vertical column and horizontal row of [Figure 1](#) which refer to several articles that do not reflect on PES effectiveness or equity outcomes. A future PES strategy ([Box 1](#)) can concentrate on a number of elements. First, scholars can continue to pursue the development of global reviews, following systematic review protocols, and ideally develop a comparable database of PES cases worldwide that can help identifying challenges and trends in PES design and implementation, looking at *both* effectiveness and equity. Those interested particularly in equity could also consider the challenge of developing syntheses of existing narratives on PES in a way that can be complementary to other reviews based on larger data and more systematic syntheses.

Second, there should be a focus on larger research projects that could follow PES implementation in multiple locations, focusing on one or various PES typologies, and based on a shared research framework — drawing, for example, on similar experiences in common-pool resource management and rural livelihoods research [78,79]. These projects should be developed in partnership with PES practitioners, not only to access sites over time for research purposes but to develop locally-informed 'theories of change' that could be tested during and/or after PES implementation. As it has been suggested elsewhere [80,81^{••}], coming up with context-specific hypotheses related to environmental and socio-economic outcomes is fundamental to rule out alternative explanations of positive or negative change — that could be wrongly attributed to PES activities-, and to provide more accurate lessons for practitioners and donors.

Third, PES research should rely on robust data and methods. Spatial land use data from remote sensing, complemented with on-the-ground monitoring transects, have been mostly applied to understand changes in the correspondent ecological outcome variables, such as forest cover or plant diversity. As regards equity outcomes, surveys and interviews have been used to reflect on PES procedural and distributional effects, such as presence of conflict, changes in resource governance, impact on relative income, and benefit sharing. The use of coupled ecological and socio-economic data in econometric matching techniques with difference-in-difference regression models can be helpful to compare performance between PES and non-PES sites of selected variables.

Precisely, involving control groups that act as counterfactuals and panel datasets of ecological and socio-economic data in PES assessment frameworks would be consistent with an increasingly common approach in impact assessments of development and conservation policy [82–84]. We recognize that such an approach involves a set of challenges related to the possibility of selecting valid land-use polygons, village and household controls, particularly in contexts of poor socio-economic and governance data availability, as well as the more recurrent problems in panel data research, including data gathering costs, data consistency and changing circumstances in both project and control groups, for example, due to migration processes. Connecting well-grounded ‘theories of change’ with measures of effect means that many studies of PES initiatives will benefit from combining research methods, and qualitative work will continue to be critical to understand how people subjectively think and feel about any observed ecological and equity effects derived from PES.

In conclusion, this article set out to review scholarship literature on PES implementation in tropical and sub-tropical regions. Our database rendered a limited number of (case) studies, which suggests that first-hand empirical evidence on ongoing schemes might be scarcer than one might think given the popularity of the policy mechanism. Seemingly, we have demonstrated that PES schemes appear to be more effective in environmental terms than socially equitable. This is probably our most worrying finding given current grounded calls for incorporating equity criteria in PES design. We have identified critical methodological gaps related to developing panel data and control-based assessments of PES distributional outcomes, particularly in relation to payment effects on household or collective incomes. In light of these findings, we have advocated for a more multi-disciplinary and integrated wave of empirical research that, on the one hand, builds on and supports the evolving and growing literature on conservation policy impact assessment and, on the other, relies on practitioners as key research

partners and on PES and research donors as key funding supporters.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.cosust.2015.06.001>.

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