



Review

Payment for Environmental Services: A critical review of schemes, concepts, and practice in Brazil

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ABSTRACT

The Payment for Environmental Services (PES) is often conceived through complex schemes without a clear definition of all concepts involved. This study presents the results of a systematic literature review on PES schemes in Brazil, accompanied by a critical assessment of their efficacy for potential environmental gains. The PES approaches were grouped into six categories based on the research focus, and those that were focused on PES policies were identified as the most studied. A particular emphasis has been given to the Amazon and Atlantic Forest biomes, where the ecosystem services studied were mostly centered on issues related to carbon and water, respectively. Approximately one-third of all schemes provided no clear definition of which ecosystem services are proposed for payment. In addition, the review showed no consensus among studies on the definition of services in similar schemes. Most schemes presented no payment system conditioned on the provision of environmental services. Furthermore, the review showed that the absence of clarity in the application of concepts may hinder the development of public policies to properly implement PES in Brazil. The conclusion is that standardizing terms used in the literature and in PES schemes is critical; therefore, the use of the Common International Classification of Ecosystem Services (CICES) as a reference is recommended to ensure clarity, objectivity and, more importantly, the expected environmental efficacy.

1. Introduction

One of the most pressing challenges of our time is to find a balance between economic development and environmental conservation (Farley and Costanza, 2010). Mismanagement of ecosystems can cause disruptions to biogeochemical and water cycles, biodiversity loss, and climate instability, resulting in risks to human health and well-being (MEA, 2005; TEEB, 2008). Therefore, ecosystem services have been identified as essential ecosystem functions that contribute to human well-being, raising public awareness about the importance of

biodiversity conservation (Costanza et al., 2017; Daily, 1997; de Groot, 1987; Gómez-Baggethun et al., 2010).

According to the Millennium Ecosystem Assessment, ecosystem services are benefits that humans obtain from ecosystems (MEA, 2005). According to Haines-Young and Potschin (2018) focusing on goods or benefits that ecosystems directly provide to humans makes the definition of services clearer and more objective, considering them as final services. In this sense, the definition is affected by the context, for example, when water is used as drinking source, it is considered the final service; however, when the focus is on recreational fishing, the fish is

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classified as the final service and the water where it lives is considered as the sustaining structure of this service (Haines-Young and Potschin, 2018). This definition supports the evaluation carried out in the present study.

Despite commonly presented differences between the concepts “ecosystem services” and “environmental services”, both definitions are in line with the original idea that addresses the importance of ecological systems and functions for humanity (Costanza et al., 2017; Gómez-Baggethun et al., 2010; Vihervaara et al., 2010). In this sense, Wunder (2005) emphasized that the difference between these concepts in the proposal of Payment for Environmental Services (PES) is minimal and chose to use the term “environmental services” by considering that they are separable by nature. The most used term in Brazil is “environmental services” (Altmann and Silva Stanton, 2018); the two terms are often used to designate the same processes and are considered as synonyms (Conceição et al., 2015; Engel et al., 2008; Pagiola et al., 2019; Parron et al., 2019; Vihervaara et al., 2010; Zanella et al., 2014).

PES has been considered a solution to achieve conservation goals by rewarding and acknowledging agents who protect the environment (Farley et al., 2010; Muradian et al., 2010; Pagiola et al., 2002), mainly in Brazil, which have significant capacity to provide such services (Guedes and Seehusen, 2012). According to Wunder (2005), PES is an instrument that facilitates voluntary and conditional agreements between buyers and sellers, based on the performance of a well-defined environmental service or land use that can guarantee the provision of such services (Wunder, 2005; Wunder et al., 2008).

However, this is not the only existing definition of PES. Muradian et al. (2010) considered PES as “a transfer of resources between social actors, which aims to create incentives to align individual and/or collective land use decisions with social interests for the management of natural resources” (Corbera et al., 2009). reported that PES aims to improve or change the management of ecosystems through economic incentives. Contrastingly to the definition of Wunder (2005), Vatn (2010) presented a broader understanding of PES, explaining that payments are connected to markets, which reconfigures the relationships between state, market, and community, making public bodies the true central intermediaries or ‘buyers’ of ecosystem services.

The increasing interest in PES has enabled the development of different structures to conceptualize them theoretically for a better understanding of the complexities and diversities that characterize their implementation (Muradian et al., 2010; Sommerville et al., 2009). However, most of them have a similar main goal: creating economic incentives for conservation and providing natural benefits. Thus, environmental services are the product of this market model. Therefore, successful PES schemes depend on clarity in definition of these services and the relationship between the land use and the provision of the defined service (Engel et al., 2008). PES schemes that do not prioritize environmental services result in a narrow perspective of their commodification, compromising their effectiveness (Bastos Lima and Persson, 2020; Fabri et al., 2018; Muradian et al., 2010).

Considering the context in which most PES schemes operate, it is common to find some that do not define environmental services, and even some that have no information about the efficiency of the land use practices assigned to deliver the desired services (Muñoz-Piña et al., 2008; Muradian et al., 2010; Salles et al., 2017). Consequently, payments often do not meet the criteria of conditionality, as they are made based on conviction rather than on actual provision of environmental services (Fearnside, 2012; Wunder, 2007). The conditionality criterion establishes that the payment is conditional on the actual provision of the service, i.e., the payments are based on results. Payments based on results can more flexibly and autonomously compensate providers of environmental services (Bredemeier et al., 2022). According to Schwarz et al. (2008), the success of result-based schemes depends on a clear definition of environmental goals and result indicators.

The absence of transparency in many PES schemes implemented around the world, mainly regarding “requested payment versus which

service will be paid”, highlights the relevance of the present study, which aims to investigate how PES schemes are currently being applied in Brazil. The guiding questions of this study, in the search for a consensus between the proposed theory and the practical application of the concept, are: Do all PES schemes in Brazil have at least one clearly defined service? What services are considered environmental services in PES schemes in Brazil? Is there a consensus among the studies on the definition of services in similar PES schemes? Do the payments meet the conditionality criterion? The analysis of these questions was based on a systematic literature review, presenting the main research trends on PES schemes in Brazil.

2. Methodology

The study was based on a systematic review divided into two phases: (i) search and (ii) systematic analysis of the literature (Jiang, 2017). The first phase of the survey involved a bibliographical search conducted in June 2020. The searched terms: “payments for ecosystem services,” “payments for environmental services,” and “Brazil”, were used in English and Portuguese languages in the following databases: Web of Science (all databases), Scopus, and Scielo. The search was limited to published peer-reviewed articles. The choice of terms used covered the divergences found regarding the concepts of “environmental services” and “ecosystem services”, limiting the results to PES schemes in Brazil. The flow of information found in this phase, including its different stages, number of records identified, maintained, and excluded, and reasons for exclusions are shown in Fig. 1.

The second phase consisted of developing a research database based on the analysis of the literature, following the example of the Ecosystem Services Assessment Database (van der Ploeg et al., 2010). The database included the following information: authors, year of publication, research focus (classification suggested from the evaluation of each work), biome, PES scheme, defined environmental services, and payment conditions (conditionality criterion).

The chosen approach for selecting the literature may not cover all researches carried out on PES schemes in Brazil. However, this approach seeks to avoid arbitrary selection of publications and exclude materials such as books, book chapters, master's theses, doctoral dissertations, reports, or technical bulletins (grey literature).

3. Results and discussion

3.1. Trends in publications on PES schemes in Brazil

The database of the systematic literature review consisted of 58 publications, published from 2008 to 2020. Six categories of research focus were identified: evaluation or monitoring of PES; impacts of payments; participation of land owners/users; PES policies (legal aspects); methodological proposals (articulation and/or implementation of PES); and environmental valuation (Fig. 2). However, studies that evaluate the application of the concept of environmental services in PES schemes in Brazil were not found.

Studies that discussed policies involving PES initiatives (38 %) and those focused on evaluation or monitoring of active PES (33 %) are the most common in Brazil. Analyses of the global scenario, institutional structures, legal aspects of payment systems, and market policies for environmental conservation are also part of most case studies on PES (Gómez-Baggethun et al., 2010). PES initiatives are politically relevant because they stimulate innovative discussions and act as inducing systems for the formation of effective ecosystem service providers (Fabri et al., 2018; Filoche, 2017). However, the structuring of these systems has often been carried out without prioritizing ecological issues, developing independent characteristics, which are often divergent, and assuming fundamentally diplomatic regional interests (Gómez-Baggethun et al., 2010; Kull et al., 2015; Taffarello et al., 2017).

Studies tend to focus on ecosystem services associated with Brazilian

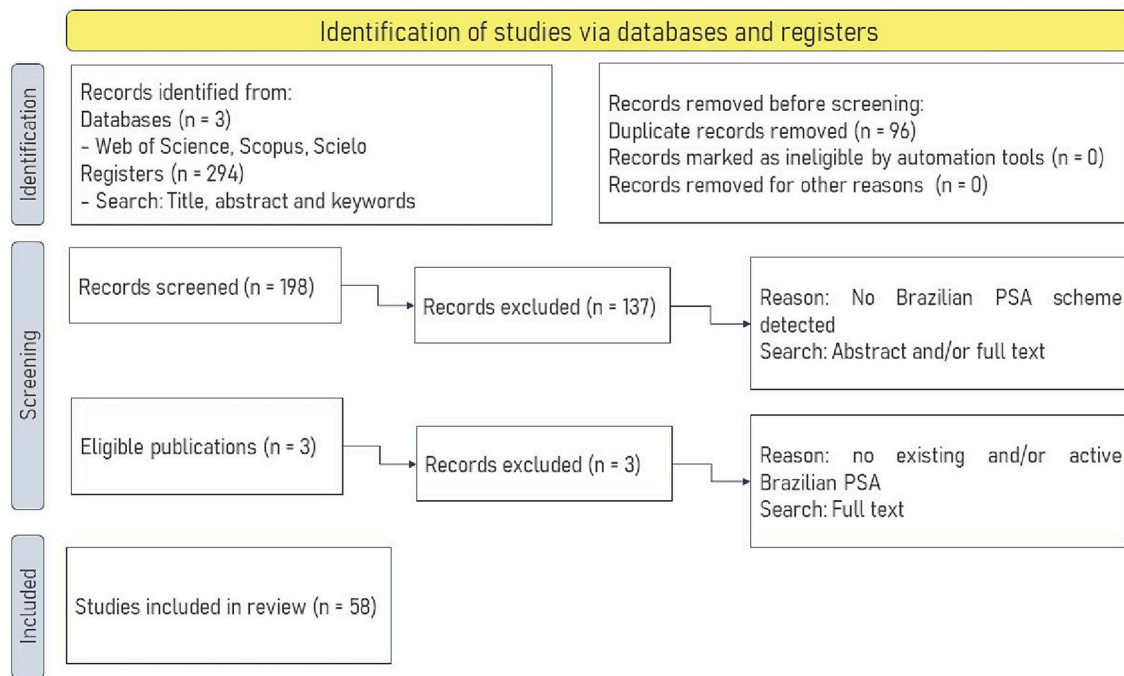


Fig. 1. Diagram of preferred reporting items for systematic reviews and meta-analyses (PRISM) based on (Page et al., 2021).

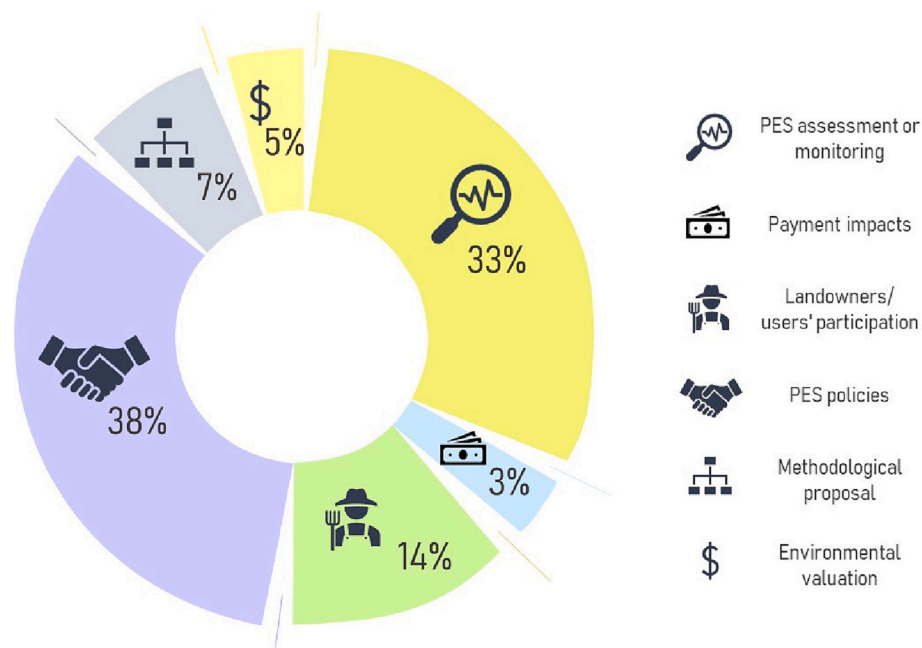


Fig. 2. Classification categories of research focus for the 58 publications that composed the database of the systematic literature review.

biomes (Fig. 3). Regarding the Amazon biome, 68 % of the 19 publications focused on PES policies, and only 5 % on PES evaluation or monitoring (Simonet et al., 2019) and participation of land owners or users (Mohammed et al., 2013). Almost all schemes consisted of carbon-related environmental services (95 %) and only 5 % consisted of multiple services in the Amazon biome (Urzedo et al., 2020). Regarding the Atlantic Forest biome, 47 % of the 36 publications focused on PES evaluation or monitoring, and 19 % on PES policies and participation of land owners or users; over 85 % of the schemes reported in these publications consisted of water-related environmental services. Regarding the Cerrado biome, only 5 publications were found, all related to water;

40 % of them focused on PES evaluation or monitoring, two of them were publications that evaluated several schemes the same manuscript, including state projects that also cover the Atlantic Forest biome, and therefore were accounted for both biomes.

Publications on PES schemes focused on the Caatinga, Pampa, and Pantanal biomes were not found. This denotes a scientific attraction to the Amazon and Atlantic Forest biomes, for which environmental services are focused on carbon and water, respectively. The growing appeal for conserving forests and reducing greenhouse gas emissions makes PES schemes for the Amazon biome to focus more on carbon-related services. The high demand for water due to the growing population stimulates

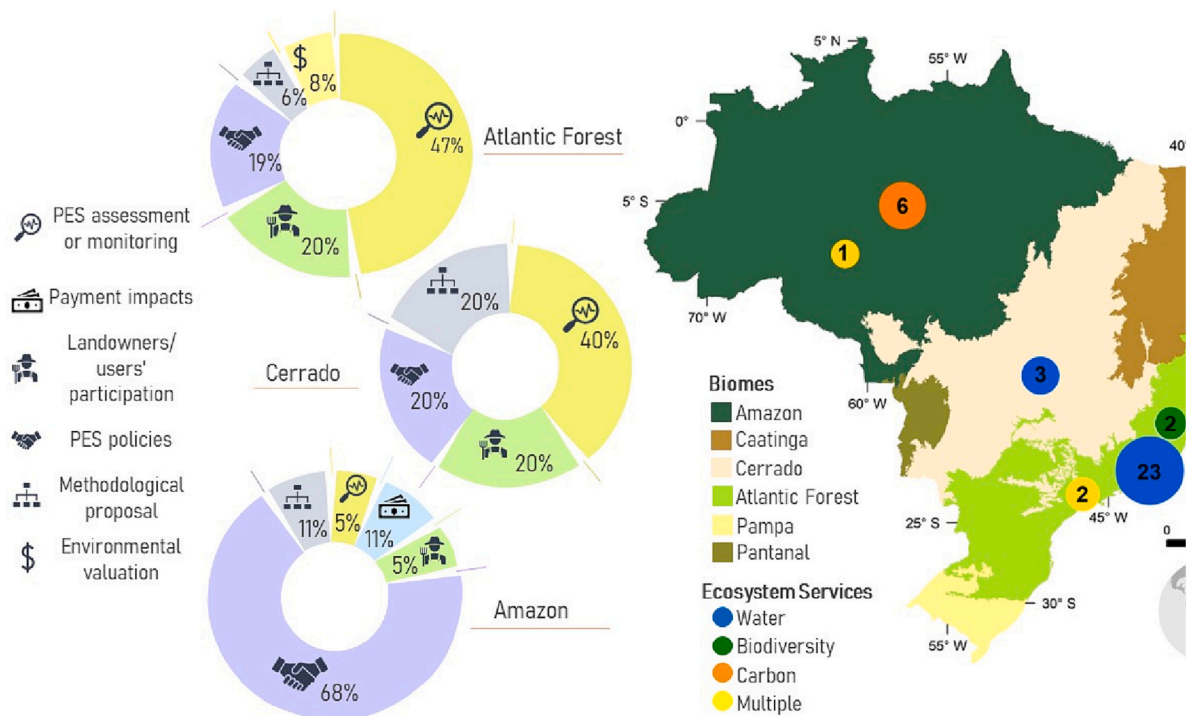


Fig. 3. Categories of researches related to Brazilian biomes and the number of PES schemes in Brazil focused on biomes and environmental services. Source: IBGE, 2019/IBGE, 2018/Bibliography Geographic Coordinate Systems: SIRGAS 2000.

most PES schemes for the Atlantic Forest biome to focus on water-related environmental services.

Considering the PES schemes identified, Bolsa Verde and Mina d'Agua are regional initiatives in states of Minas Gerais and Sao Paulo, respectively, that were implemented locally in the Cerrado and Atlantic Forest biomes, therefore, they were accounted for both biomes. The Produtor de Agua program of the ANA was mentioned in two publications. This program is an initiative of the Brazilian federal government to support local payment schemes, mainly in the Atlantic Forest biome (ANA, 2020), as well as the Conservador das Aguas project. However, it was not possible to include the Produtor de Agua program to this result, as there is no clear evidence that at least one of the PES schemes connected to the program is running in any Brazilian biome.

There is evidence of more than 200 economic incentive initiatives for environmental services in Brazil (Forest Trends, 2015), but only 37 active or concluded PES schemes were mentioned in the reviewed literature; the Conservador da Aguas project was the most cited (Fig. 4). Out of the selected studies, 69.44 % referred to water-related schemes. This result corroborates those of Zanella et al. (2014), who consider payment initiatives for the protection of watersheds as the best well-known environmental conservation incentives in Brazil. Studies that referred to carbon-related environmental services were the second most found (16.67 %) and only 8.33 % of the studies referred to more than one type of environmental service. Biodiversity-related environmental services were the least mentioned (5.56 %) among the highlighted environmental services.

Most reviewed publications evaluated only one service and some did not consider ecological interactions with the environment (Figs. 3 and 4). Focusing on only one service may undervalue others important services for ecological balance, as well as limit the attention to specific ecosystems, not taking advantage of the potential of all natural systems (Kull et al., 2015; Martín-López et al., 2014; McAfee, 2012). Studies that connect carbon sequestration and storage considering only standing forests, mainly the Amazon rainforest, fail to consider that around 30 % of the carbon storage potential of the Amazon rainforest is attributed to the soil (Cerri et al., 2006).

Soils are important carbon reservoirs; the estimated amount of carbon stored in soils is greater than those found vegetation and atmosphere (Carvalho et al., 2010). Soil carbon contents are strongly affected by land use and management; however, natural components of soil structure can also affect the soil natural potential to store carbon, such as texture, aggregation, sedimentation, and organic matter content (Machado, 2005; Zinn et al., 2012). In this sense, when disregarding the forest vegetation and considering only the soil type, the evaluation may show, for example, that sandy soils, which are predominant in the Amazon region, have a lower natural potential for carbon storage than clayey soils, such as Oxisols. This implies that the provision of this service may be underestimated in other potential areas of the country that have different forest density and characteristics, such as the Cerrado biome (Bustamante et al., 2006).

Grouping or not several services into a single initiative is one of the many debates surrounding PES schemes. Several authors agree that grouping is important to ensure the success of PES (Brançalion et al., 2014; Strassburg et al., 2012; Viani et al., 2018; Wendland et al., 2010). Others warn that some services are contradictory to each other and choosing one of them can cause the degradation of another, and report the existence of “trade-offs” in choosing services (de Groot et al., 2010; Martín-López et al., 2014; Rodríguez et al., 2006). This denotes how PES schemes are inherently complex.

3.2. How PES schemes incorporate concepts of environmental services

3.2.1. PES schemes without clearly defined environmental services

Approximately 33 % of the evaluated publications did not present a clearly defined environmental service for the analyzed PES, but most reported the conditions for payments for these services (Table S1 in the Supplementary Materials). How can there be a payment for an undefined environmental service? According to Wunder (2005), every PES should have at least one environmental service in evidence and the payment for this service should comply with the conditionality criterion: payment for the provision of the established service. Non-compliance with this criterion encourages providers to not commit to the main

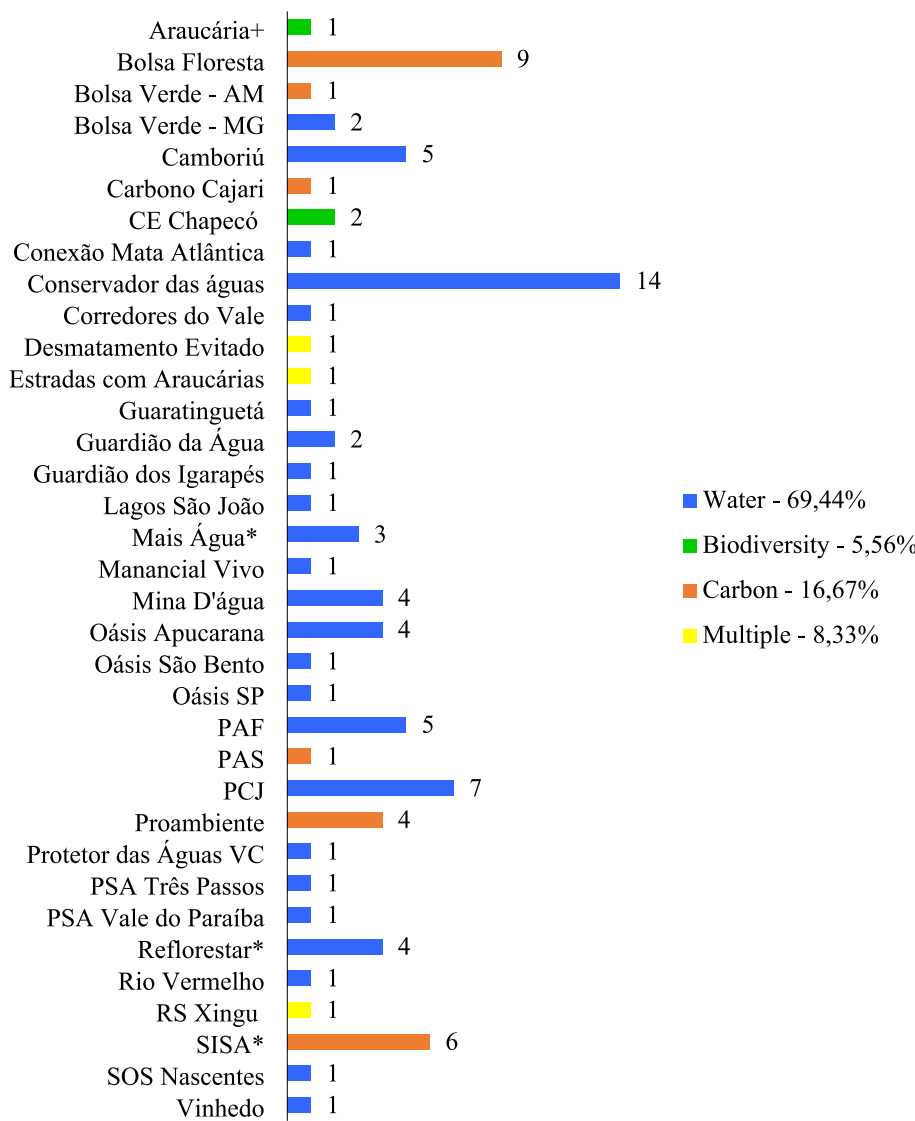


Fig. 4. Number of citations of each PES scheme in Brazil in the reviewed literature.
 *More than one PES scheme was accounted for the Reflorestar program, which is a program of the state government of the state of Espírito Santo (ES) based on two previous pilot projects: Florestas para a Vida e ProdutorES de Agua (Chiodi and Marques, 2018; Taffarello et al., 2017; Zanella et al., 2014); Produtor de Agua program - Sao Francisco Xavier (Taffarello et al., 2017) was counted together with Programa Mais Agua (Fiore et al., 2020, 2017); and the first certification program, State Program of Certification (Eloy et al., 2012), was considered together with SISA, as they are related initiatives.

goal and consider the available subsidies as political favors or merely as a right (Fearnside, 2012). Furthermore, failure to deliver the intended final benefits is considered a loss of financial and political investment and generate insecurity and discourage investments in potentially efficient initiatives (Engel et al., 2008; Fearnside, 2012; Salles et al., 2017).

The focus on environmental services differs from the typical approach in the common commercial market, as it prioritizes the development and promotion of sustainable production methods that ensure environmental conservation (Greenleaf, 2020). Therefore, the lack or inadequate definition of environmental services can affect the effectiveness of the PES in achieving their intended goals of valuing and preserving the environment and in properly determining the payments (Fabri et al., 2018; Muradian et al., 2010; Salles et al., 2017). Richards et al. (2015) provided a general definition of the services covered by the Conservador das Águas project, referring to them simply as “water-related ecosystem services”. However, they did not specify the benefits for which the program provides payment, whether for higher quantity and/or quality of water, whether the water is intended for urban supply, irrigation, or animal watering, or other. This denotes that the evaluation, monitoring, actions, and even the payments of PES schemes may have nothing to do with the service that was defined or generated.

Another problem found in these definitions is that some authors name ecosystem structures or functions as environmental services,

without making it clear whether they are, or generate the benefits that are intended to be rewarded. Therefore, the definition of environmental services in PES schemes should follow the Common International Classification of Ecosystem Services - CICES (Haines-Young and Potschin, 2018), as the definition of final services will be clearer and more objective, resulting in greater capacity for evaluation, monitoring, and transparency in transactions.

According to Santos and Silvano (2016), the environmental services defined for the Tres Passos program were forest conservation and restoration, and the program's goal was to increase water availability and preserve water sources and springs. Therefore, the final environmental service of this program is the provision of water for public supply, and the conserved and restored forest is possibly one of the structures that maintain this service. However, evaluation and monitoring are necessary to know the efficiency of this structure in generating the intended final service. The debate about whether expanding or restoring forest cover can improve water supply services persists (Filoso et al., 2017). In this sense, if the program considers the maintenance of a structure as the final service, how can it ensure that the program's objective is being properly evaluated, monitored, and achieved? It is important to emphasize that the sustaining structure can also be considered as a parameter for payment, as long as it effectively contributes to the environmental service proposed in the PES (Wunder,

2005).

In this sense, only 40 % of the studies (23 publications) presented the definition of environmental services in accordance with the concept of Haines-Young and Potschin (2018) (Table S2 in the Supplementary Materials). Most of the studies that met this criterion referred to water-related PES schemes, denoting greater difficulty in presenting direct benefits for services that are not related to water. Some authors reported several environmental services with only few of them providing evident direct benefits, such as scenic beauty and climate regulation, and therefore were considered in the results of the present study (Conceição et al., 2015; Hall, 2008a; Tagliari et al., 2019; Urzedo et al., 2020; Zolin et al., 2014, 2011). Taffarello et al. (2017) and Tagliari et al. (2019) did not present final services for all PES analyzed.

The analysis carried out to determine the direct correlation between payment terms and proposed final services showed that about 34 % (8 publications) of the payments did not meet the conditionality criterion advocated by Wunder (2005); all the other payments were made for land management practices (Table S2 in the Supplementary Materials). This result indicates that no scheme directly pays for providing a final environmental service. Furthermore, while land management is regarded as a prerequisite for payment, provided it delivers the service (Wunder, 2005), this association is often based on assumptions, and the actions may be compensated without information that the proposed environmental service has been provided (Fiore et al., 2017; Hall, 2008b; Muradian et al., 2010; Wunder, 2007). Hall (2008a) studied the Proambiente program and found that even after four years of operation, payments were made based on limited evidence without effective guarantee of the generation or maintenance of the proposed environmental services. Some PES schemes, such as Bolsa Floresta and Bolsa Verde, did not have any monitoring practices or methods of certifying compliance with the conditionality criterion (Alves-Pinto et al., 2018). Taffarello et al. (2017) evaluated sixteen water-related PES schemes and found that only five had some water monitoring practice.

Therefore, conditional rewards are considered a challenging criterion to implement in practice (Sunderlin et al., 2015). One of the main limiting factors for compliance is the absence of effective indicators that show a realistic connection between service provision and payments (Sone et al., 2019; Tagliari et al., 2019; Wunder, 2007). The integration of low-cost, easy-to-apply quantitative indicators can improve the monitoring accuracy and, consequently, the credibility and effectiveness of PES schemes, mainly when implemented from the project characterization and implementation stages (Martínez-Jauregui et al., 2019; Reed et al., 2008; Sone et al., 2019; Zanella et al., 2014). In addition, the definition of the final environmental services is essential for selecting the appropriate indicators. A project that aims to reward for the increase in water quantity should use indicators that evaluate water flow in the designated area, whereas services related to soil conservation should use indicators that measure the soil physical quality, such as indicators that assess soil porosity and density.

It is emphasized that the purpose of this analysis was not to assess the efficiency of pre-established criteria for rewards, but rather to evaluate their direct connection with the proposed and delivered final services. In this analysis, contracts based on actions were not considered inferior to those based on results. However, the primary objective was to encourage the monitoring and evaluation of all types of contracts. Despite the challenges associated with the implementation of these contracts, payments based on results are essential for reducing discrepancies in information (Engel et al., 2008; Salles et al., 2017). The absence of monitoring, quantification, or certification of effectiveness can cause payments to be seen as social transfers (Conceição et al., 2015; Salles et al., 2017; Superti and Aubertin, 2015), such as Bolsa Floresta, whose payment terms include enrolling children in school (Agustsson et al., 2014; Alves-Pinto et al., 2018; Mohammed et al., 2013); or those that pay only for registering for the program, such as Conservador das Aguas and most initiatives that involve policies for reducing emissions from deforestation and forest degradation (REDD+) (Richards et al., 2017;

Ruggiero et al., 2019; Salles et al., 2017).

Several authors consider that numerous initiatives labeled as PES in Brazil are just public incentive devices for sustainable development or forest conservation projects (Filoche, 2017; Kull et al., 2015; Rival, 2013; Salles et al., 2017; Superti and Aubertin, 2015). These initiatives often employ the term “ecosystem services” or “environmental services” as a rhetorical tool to boost fundraising, without necessarily prioritizing payment for the preservation or provision of these services (Gómez-Baggethun et al., 2010; Kull et al., 2015; Superti and Aubertin, 2015). Moreover, since social factors can affect the provision of ecosystem services (FAO, 2018; MEA, 2005; Wunder, 2005), some projects end up prioritizing poverty alleviation, and the environmental service becomes a form of “gift” (Conceição et al., 2015).

Inconsistencies in information were found among publications that describe the same PES scheme, mainly regarding payment terms (Table S2 in the Supplementary Materials). Payments from the Conservador das Aguas program, for example, can vary from simply register for the program (Richards et al., 2017; Ruggiero et al., 2019) to use soil conservation practices (Bremer et al., 2020) or engage in forest conservation and restoration and health care initiatives (Cruz et al., 2017; Zolin et al., 2014, 2011). Therefore, a comprehensive understanding of payment systems requires research that extends beyond the scope of scientific literature analysis. Similarly, inconsistencies were observed in the definition of environmental services, particularly when the authors did not specify a final service. Publications that referred to the water-related program Camboriu described services ranging from water services (Kroeger et al., 2019; Taffarello et al., 2017) to maintenance of roads (Santos and Silvano, 2016) (Annex).

This denotes that incompatibility of information and even distortion of concepts of environmental services and their payments are sometimes due to the scientific approaches, rather than the original proposals of the PES schemes studied. However, a clear and precise definition of environmental services is essential for conducting critical analyses of different programs (Haines-Young and Potschin, 2018; Martin-Ortega et al., 2013; Obiang Ndong et al., 2020). The review study on PES schemes across Latin America conducted by Martin-Ortega et al. (2013) showed that the absence of a clear and distinct definition of services is one of the factors that generate controversy between the actual process of design and operation of PES schemes and their description in the literature. Therefore, in addition to the development of projects that allow standardization and comparison between different types of initiatives, clarity and agreement in the definitions attributed by the scientific community are also necessary.

These discrepancies in the conceptualization and description of payments for PES schemes can have implications on the formation of public policies. The Brazilian National Policy for Payments for Environmental Services (PNPSA) was established in January 2021 through the Law 14,119. According to the PNPSA, ecosystems lose prominence when the term “ecosystem services” is defined differently from the term “environmental services”. Ecosystem services refers to the benefits generated by ecosystems, whereas environmental services refer to individual or collective activities that promote the maintenance, recovery, or improvement of ecosystem services (BRASIL, 2021). This definition in the Brazilian legislation corroborates that of Karsenty and Ezzine-deblás (2016), who defined environmental services as “services provided by people to other people”.

The issue is not necessarily the differentiation between the two definitions, but the focus placed on “environmental services”, in which the main character of the narrative is the human being and not the ecosystem. Consequently, no PES initiative in Brazil pays directly for the provision of a final “ecosystem” service, but rather for human actions or activities defined as environmental services under the law. Additionally, this approach in national legislation discourages the evaluation and monitoring of actual service provision while promoting payments based on assumptions (Alves-Pinto et al., 2018; Fiore et al., 2017; Hall, 2008b; Muradian et al., 2010; Taffarello et al., 2017; Wunder, 2007).

Following the original concept of ecosystem services, ecosystems and their inherent functions are the main contributors to promoting human well-being (Costanza et al., 2017; Gómez-Baggethun et al., 2010). Therefore, defining what is considered a service is essential to avoid tangential benefits, mainly in the context of PES schemes, which pay for the provision of the proposed services. Thus, the definition of environmental services in PES schemes should follow the methodology of final services (Haines-Young and Potschin, 2018) to ensure clarity in the intended benefits and increase confidence in the policies and transactions established. Furthermore, the wider the range of actions that qualify for payments, the greater the challenging to raise adequate financial resources for the functioning of PES, hindering the promotion and dissemination of this policy. According to Wunder (2005), the effectiveness of PES schemes also depends on avoiding the imposition of collateral objectives that may compromise their functionality.

4. Conclusion

Several limitations related to transparency and application of concepts in publications on Payment for Environmental Services (PES) schemes in Brazil were identified. In general, the actual impact of PES schemes on the provision of environmental services is not fully understood, as no scheme pays directly for the provision of a final service, and most do not meet the conditionality criterion, which establishes that the payment is conditional on the actual provision of the service. Studies that evaluate the application of the concept of environmental services in PES schemes in Brazil were not found in the literature. The absence of clarity in the definition and application of the concept of environmental services and payment terms can affect the formation of public policies in Brazil and compromise the effectiveness and dissemination of PES initiatives in the country. Therefore, the definition of final environmental services established by the Common International Classification of Ecosystem Services (CICES) should be used as a reference to ensure the effective provision and payment of environmental services established in PES schemes.

CRedit authorship contribution statement

Paula Mota, Adriana Monteiro and Rachel Prado conceptualized the study. Paula Mota guided the research and wrote the draft version, while Adriana Monteiro supervised the work. The remaining authors participated in discussions that improved the final work. Fernando Pacheco edited the draft version and checked formality.

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.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.scitotenv.2023.165639>.

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