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Review Paper

Brazilian payment for environmental services programs emphasize water-related services

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ABSTRACT

Based on “user pays” and “provider gets” principles, the Payment for Environmental Services (PES) consists of providing economic incentives or compensation for land users who adopt activities that promote ecosystem services. These PES initiatives have grown rapidly in Brazil over the last few decades, however, studies that address the panorama of these programs in the country are still scarce, regional, or outdated. Here, we investigate the PES overview in Brazil through interviews and an extensive literature review. We found in total 80 PES programs implemented in Brazil, of which 14 were closed. The programs are poorly distributed across the country, mostly concentrated in the Atlantic Forest (56.25%) and Savanna (36.25%) biomes, in Southeastern Brazil. The majority of programs primarily prioritize improving water quality and quantity. Therefore, reforestation, protection of native vegetation, and soil and water conservation are their main proposed practices. The positive impacts of Brazil's PES experiences are evident; while the lack of transparency and monitoring, and poor spatial and financial distribution are still major limitations. We conclude that if correctly implemented, PES schemes offer a path to reconcile environmental conservation with agricultural production in Brazil.

1. Introduction

The survival and well-being of human society are inseparable from the services provided by ecosystems (Wallace, 2007). In the last centuries, human activities have substantially changed natural ecosystems, mainly driven by the underlying demands for food, water, and energy from a growing population, causing direct impacts on ecosystem services (ES) (Carpenter et al., 2006; Liang et al., 2017; Nyangoko et al., 2022; Strauch et al., 2013). Unsustainable land-use change results in several damages such as soil erosion (Oliveira et al., 2015), nutrient depletion (Qin et al., 2020), water scarcity (Sone et al., 2019), salinity, pollution, loss of biodiversity, land desertification and silting of rivers (Bai et al., 2013).

The practice of Payment for Environmental Services (PES) emerged as a strategy to deal more consciously with the trade-offs between environmental and development objectives. Following the “user pays” and “provider gets” principles, those who contribute for the generation of ecosystem services must be paid for it and whoever benefits must pay for it. Therefore, PESs are characterized as economic incentives or compensation for land users who adopt activities that promote ES (Chen et al., 2012; Mayrand & Paquin, 2004; Wunder, 2015). In this way, PES programs play the role of an ES market because they connect ES providers to their users and are important mechanisms for promoting social, economic, and environmental sustainability, especially in rural areas (Maciel et al., 2014).

PES has gained popularity due to its ability to assist decision-making within the current institutional economic context (Gómez-Baggethun et al., 2010), its appeal to donors (Wunder,

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2015), its potential to stimulate developing rural economies (Schomers & Matzdorf, 2013) and achieve environmental compliance through ecological restoration (Richards et al., 2015; Viani et al., 2017). Overall, four main pillars support the expansion of PES: buyers and sellers motivated by the perception of scarcity of the ecosystem service or good, metrics that capture a fair value of the service, and low-transaction-cost institutions that, for example, collect funds from diffuse beneficiaries (Salzman et al., 2018).

There are at least 550 active PES worldwide, totalizing about US$ 36 to 42 billion in annual transactions (Salzman et al., 2018). Despite the magnitude of this number, developing countries receive less than USD 1 billion per year for biodiversity conservation (Milder et al., 2010; Parker et al., 2012; Wunder et al., 2008), which is not enough to minimize global biodiversity losses (Hein et al., 2013). Criticisms to PES point out the commodification of nature and raise questions about the capability of PES programs to promote integrated socio-ecological policies (Calvet-Mir et al., 2015; Corbera et al., 2007; Schröter et al., 2014). Despite the critiques and challenges, analyses of PES effectiveness in the tropics indicate that payments have been favorable to land cover and biodiversity, and has the potential to promote sustainable environmental governance (Adhikari & Baral, 2018; Calvet-Mir et al., 2015).

Brazil has been experiencing a "PES boom" since the early 2000s, becoming one of the countries with the highest number of PES programs in the world (Bennett & Carroll, 2014; Pagiola et al., 2013). For more than two decades the Brazilian States and Municipalities developed their own legislation and initiatives, as the Brazilian National Policy of Payments for Environmental Services was created only in 2021, through the Federal Law No. 14.119/2021. Despite this increasing popularity of PES, studies that address all these programs in Brazil are still scarce, regional, or outdated (Bremer et al., 2016; Jones et al. al., 2020; Pagiola et al., 2013). A relevant initiative to assess the national scenario, barriers, and opportunities for PES in the country was the Matrix of Ecosystem Services Brazil, created in 2015 by the Non-Governmental Organization Forest Trends and available at https://brazil.forest-trends.org/(Forest Trends, 2015). The initial plan is that there was a continuous update of the Matrix to serve as a platform for sharing knowledge and opportunities on issues of environmental services, however, the program did not continue (Born, 2016).

The growing trend of PES programs suggests a clear need to survey the geographic distribution of programs in Brazilian territory, places that have not yet been reached and have needs to be met, the distribution and availability of resources, potential investors, debates on sociopolitical contexts and factors that contributed to or impeded the growth of programs. As a result, there is still a large gap in critical analysis of projects established to serve as a reference and improve approaches for existing and future programs.

The objective of this study was to develop an overview of PES in Brazil identifying the spatial and temporal distribution of programs, as well as the duration, the distribution of funding among the states and biomes, the programs goals, the activities adopted, the monitored parameters, and the potential partners and investors of the programs. Finally, we present evidence of the positive impacts of payment for environmental services programs in Brazil and discuss obstacles and challenges to the smooth running of the programs.

2. Material and methods

The strategy for developing the compilation of up-to-date information about the PES projects in Brazil was based on literature review, data directly provided by the National Water Agency (ANA), and email and/or phone interviews with program representatives.

2.1. Literature review

A bibliographic survey of the Brazilian experiences of PES was carried out by using Google Scholar, Scientific Electronic Library Online (SciELO), and SCOPUS databases. The research period was until April 2022. We prioritize peer-reviewed articles, but due to the low availability of published data on PES projects, we also considered grey literature sources.

The keywords used during the search were "payments for ecosystem services" OR "payments for environmental services" OR "economic incentives", as well as their correspondents in Portuguese. Search filters were used with the terms displayed in keywords, the abstract and the title. Then, the articles eligibility was determined in the systematic review by the adoption of inclusion criteria, set as the presence of search strings and terms with close meaning and convergence with the research objectives. Therefore, articles that did not match the search strings were excluded, as well as articles that were not compatible with the research objectives.

2.2. Data collection from the National Water Agency

We contacted the National Water Agency (ANA) via e-mail for detailed information about the projects regarding: the location, program start date, funding values, and status (PES active, PES not active, in development or closed). Active PES represent programs that are ongoing and participants have been receiving regular payments. Programs with inactive PES are in progress, but the participants are not being paid due to lack of financial resources.

The programs that are in the implementation phase are still electing the participants or resolving bureaucratic issues such as documentation. While the ongoing programs have already launched the public calls, the participants have already signed up and had their proposals approved. Closed programs are those that did not renew their contracts with participants due to they had reached the program's goal or because of the lack of financial resources. Therefore, it was possible to quantify the number of implemented programs, the total invested by state and biome, and the trajectory of the PES programs over time.

2.3. Interviews

The PES programs head were contacted by email and/or by phone call during January through June 2021. They were asked about the program implementation date, the program status, that is, whether they were still active or had already been terminated, the objectives, conservation activities implemented, the total area restored and the results obtained from the changes, the monitored parameters, the partners involved and the total investment in each project. The objectives of the programs were grouped into eight main categories: (1) water discharge (amount and/or timing of flows); (2) water quality (in general or in relation to specific pollutants and/or associated treatment costs); (3) biodiversity (protection or restoration of ecosystems); (4) sanitation; (5) sediment reduction (soil erosion control); (6) vegetation increase; (7) socioeconomic conditions (related to governance, education, livelihoods, etc.); and (8) conservation of natural scenic beauty. Program activities comprise: (1) protection of Permanent Protection Areas (APP) (through physical barriers/fences); (2) reforestation; (3) rural wastewater services; (4) dirt road management; (5) soil and water conservation; and (6) environmental education.

Collaborators were grouped into private/for-profit companies, public utilities, and third sector (non-governmental organizations (NGO)/foundation/civil society). Respondents could select one or more options for objectives, activities, and partners. The funding

data for the programs was separated by States and analyzed according to the US dollar (1 USD = R$ 5).

3. Results and discussion

3.1. Number of PES programs in Brazil

The systematic review resulted in 18 peer-reviewed articles, 8 books, 6 conference proceedings, 11 PhD and MSc dissertations, 28 Government documents (public notices and laws) and 22 websites (agencies, institutions, NGOs, Municipalities, etc.). We found a total of 80 PES projects, where 54 (67,50%) are included in the framework of the program *Produtor de Água* (literally translated "Water Producer"), developed by the Brazilian National Water Agency (ANA), which has been the main reference for ongoing initiatives. This program stimulates rural landowners in strategic hydrographic basins, through remuneration, to adopt conservation practices, supporting the improvement, recovery, and protection of water resources, aiming at reducing soil erosion and siltation in waterbodies and, consequently, increasing water quality and regularizing water supply (ANA, 2012). The remaining 26 projects are included in other 23 programs (see Table S1, Supplementary material).

The first PES program started in 1997 in the municipality of Joinville, Santa Catarina State, as part of a municipal policy to encourage the conservation of water resources. Since then, an increase in the number of implemented programs is observed, especially in 2017 when 15 new projects were created within the Water Producer program (Fig. 1).

The increasing trend in the number of PES programs in Brazil found in our study corroborates with the expected emergence of PES in Latin America watersheds reported by Bennett and Carroll (2014). According to their study, in 2013, Brazil had 25 active watershed investment programs out of 403 worldwide, ranking third only behind China (with 139 programs) and the United States of America (with 93 programs). Comparing Brazil's PES scenario with Europe's, in 2015, while there were 34 operational programs in the whole continent, most of them in Ireland (12), France (5), and Germany (4) (Bennet et al., 2017), we found that there were 51 implemented in Brazil until that period. Hence, the country has a significant number of PES programs implemented and has stood out in the search for environmental improvements using this approach.

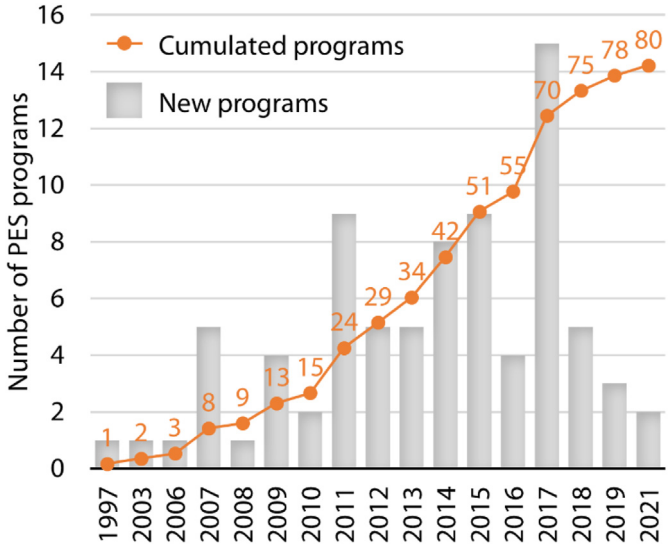

Fig. 1. Number of Payments for Ecosystem Services (PES) programs in Brazil.

We found that 63.75% of the programs are in progress, 17.50% had their contracts expired and were not extended, 15.00% did not provide information on the current status of the project, and 3.75% are still in the implementation phase. Among the programs that are in progress, 31.25% of them are not making payments for environmental services to the participants. In other words, there is an agreement active, but it is not in full working, since the farmers are not receiving money to carry out the project. Although in some cases the payments seem to be of low value, the lack of payments may affect the good development of the program, as they provide a change in the perception of the importance of ecosystem services, providing changes in habits in favor of environmental conservation, and generating a feeling of recognition of the farmers as beneficiaries of society.

3.2. Distribution of PES programs in the Brazilian territory

The PES programs take place in all regions of Brazil, however, most of the projects are concentrated in the Southeast - SE, mainly in the states of Minas Gerais (with 22 projects) and São Paulo (with 12 projects). Concerning the distribution of PES programs across Brazilian biomes, the imbalances evident in Fig. 2. The Atlantic Forest concentrates most of the programs (56.25%), followed by the Cerrado, the Brazilian Savanna (36.25%). Despite the well-known regional and global relevance as a biodiversity hotspot and in the biogeochemical and climatic functioning of the Earth system, there are only two PES schemes in the Amazon (6.25%). There is a single program in Caatinga (1.25%) biome, while the Pantanal and Pampa biomes have no programs yet. PES initiatives have expanded in the Atlantic Forest, on average, by 1.5 new Water-PES projects per year (Taffarello et al., 2017). The Atlantic Forest is considered the most degraded biome in Brazil, which may explain this concentration of restoration projects in this biome (Guerra et al., 2020; Rezende et al., 2018; Strassburg et al., 2017), but does not cancel out the need to expand PES programs in other biomes.

The Pantanal biome is part of the Ramsar Convention on Wetlands of International Importance (Willink et al., 2000); It is also considered one of the 37 largest remaining wild areas on Earth (Mittermeier, 2002). In addition, it has populations of many endangered species (Alho & Sabino, 2011). Despite this, the biome has been threatened due to fires resulting from the long drought added to the advance of agriculture and livestock (Oliveira-Junior et al., 2020). The use of fire is a traditional management tool in agriculture to eliminate waste and promote the renewal of pastures and cropland (Bayne et al., 2019; Garcia et al., 2021). However, due to dry vegetation and wind, this practice contributes to the uncontrolled spread of fire and they often spread to woods and forests (Costa & Thomaz, 2021). Removal of natural vegetation eliminates food and shelter, especially for forest-dwelling wildlife (Boer & Dios, 2020; Brando et al., 2019). As a result, the loss of biodiversity and its associated natural habitats in the Pantanal occurs as a result of unsustainable land use.

One solution to prevent the recurrence of fires is to combat the human causes that intensify drought conditions, such as implementing actions to protect springs, regulate the use of fire, allocate fire brigades before the dry seasons, and reduce deforestation caused by the expansion of agriculture and livestock. These measures could be encouraged through the implementation of PES programs, which would induce stakeholders to adopt initiatives that balance economic interest and nature protection, since the biome does not yet have any programs.

Likewise, the Pampa biome, despite being one of the largest and richest areas of pasture in the world, with a great diversity of animal and plant species (Jaung & Cols, 2019), has not yet been

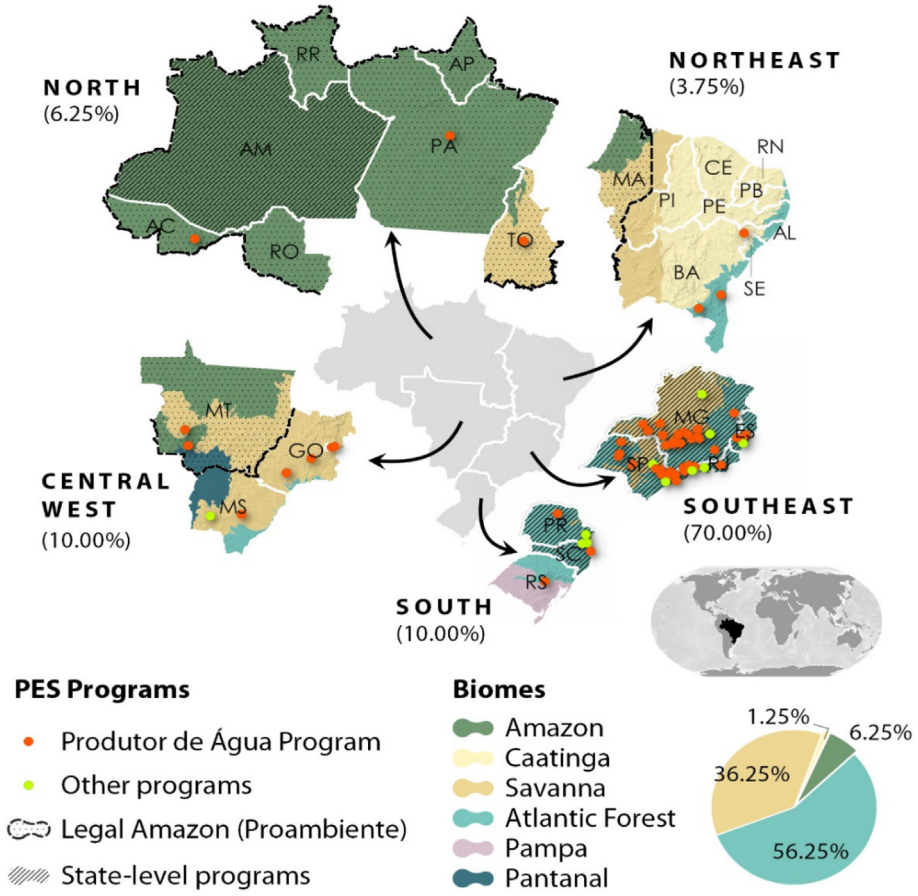

Fig. 2. Distribution of Payments for Ecosystem Services (PES) Programs by biomeand state in Brazil. States: AC – Acre; AL – Alagoas; AM – Amazonas; AP – Amapá; BA – Bahia; CE – Ceará; DF – Distrito Federal; ES – Espírito Santo; GO – Goiás; MA – Maranhã; MG – Minas Gerais; MT – Mato Grosso; MS – Mato Grosso do Sul; PA – Pará; PB – Paraíba; PR – Paraná; PE – Pernambuco; PI –Piauí; RJ – Rio de Janeiro; RN – Rio Grande do Norte; RS – Rio Grande do Sul; RO – Rondônia; RR – Roraima; SC – Santa Catarina; SE – Sergipe; SP – São Paulo; TO – Tocantins.

included in PES programs. Some of these species are threatened with extinction and in addition, the Pampa is on the flight path of many migratory birds, which provide vital ecosystem services (Jahn et al., 2017). Regarding natural protected areas in Brazil, the Pampa is the biome with the lowest representation in the National System of Conservation Units (SNUC), representing only 3% of the Brazilian continental area protected by conservation units (MMA, 2022).

The natural grasslands of the Pampa biome can be maintained by moderate grazing by large ruminants that traditionally occupy the area, offering a place where food production and conservation of the natural habitat can coexist. However, a trend towards land use change has been observed, particularly through the conversion of grassland vegetation to grain agriculture (especially soybean cultivation) and forestry (Nabinger et al., 2009). Therefore, the conversion of natural pastures into agricultural lands has resulted in an important loss of biodiversity, landscape fragmentation, invasion of exotic species, soil degradation and de-characterization of the natural landscapes of the Pampa (Boldrini, 2009; Carvalho & Batello, 2009; Gautreau, 2014, p. 293). This happens because livestock farming often becomes inefficient, due to management practices that cause overgrazing, low productivity, and low financial income (Barcellos et al., 2011; Nabinger et al., 2009). As a result, in 2009, an initiative called Alianza del Pastizal was developed, which certifies and labels products generated in natural fields of the Pampa (Parera & Carriquiry, 2014). Certification/labeling encourages consumers to pay a little more for products that are "environmentally friendly" (Altmann & Berger Filho, 2020). In this way, the rural owner obtains a competitive advantage in the market, in addition to benefiting from the increase in the price of the product.

Despite validating the importance of this initiative, Altmann and Berger Filho (2020) conclude that the conservation of ecosystems and biodiversity on private properties is closely associated with the rest of the farm and that it would be important to develop economic incentive schemes that consider a holistic view of the property. Furthermore, the authors state that the initiative requires that at least 50% of the total area of the property be native vegetation in order to be certified. Hence, the implementation of PES programs could leverage the restoration of native vegetation on properties, enabling rural landowners to adhere to the certification and labeling project. In addition, PES programs could contribute to the adoption of technologies related to herd management and other activities on the farm, improvement of existing natural pastures, sewage treatment, among other conservation measures. The PES programs, together with the Alianza del Pastizal initiative, would encourage sustainable use for livestock, preventing landowners from converting Pampa fields into other agricultural activities in search of economic improvements.

The caatinga biome has only one PES program implemented, but the loss of vegetation cover, changes in the local microclimate and accentuated water deficit, due to changes in land use, demonstrate the need for greater coverage of this biome (Silva et al., 2020).

Although the Brazilian semi-arid region naturally suffers the reflection of high rainfall variability, with rains concentrated over time, with little spatial distribution, this condition has been intensified by deforestation, fires and traditional agricultural practices through inadequate soil management, providing the expansion of desertification, reducing opportunities for rural development in these regions and affecting local socioeconomic conditions (Palacio et al., 2013; Silva et al., 2019a; 2019b, 2020; Tomasella et al., 2018).

We noted that there are other driving factors, in addition to the vulnerability of the Atlantic Forest biome, for the implementation of Água-PES programs in this region, such as the demand for water supply by the Cantareira System, located in this biome (Richards et al., 2017). The Cantareira System is the main source of water for the metropolitan region of São Paulo, which is the most populous city in Brazil. This region has been through several water crises, which has raised political debates and concern about the impact of environmental degradation in the watershed (Gesualdo et al., 2019). This was the context of the creation of the first PES scheme of ANA's Water Producer program, *Conservador de Água* project, implemented in 2005 in the municipality of Extrema, Minas Gerais, located in the Atlantic Forest biome. In addition, the Water Producer project in the watersheds of the rivers Piracicaba, Capivari and Jundiaí (PCJ), the Bolsa Verde (Minas Gerais) and Mina d'Água (São Paulo) programs were also developed in the context of the Cantareira System.

Although Brazil has the largest water reserves in the world (Getirana, 2016), the population density does not follow the distribution of these reserves, making it difficult for demands to be met. The author states that, the Southeast (SE) and Northeast (NE) regions of Brazil contribute with only 7% and 6% of the total surface water, respectively, while they include most of the country's population, with 39% and 25%, respectively. As well as the Southeast region, the Northeast region also suffers from water scarcity. However, PES initiatives are scarcest in this region, with only 3 programs and low investments (Fig. 2 and Table S1). The uneven distribution of programs in the country may be explained by the difference in economic importance, as the state of São Paulo alone contributes nearly a third of Brazil's gross domestic product (GDP), while the nine states that make up the NE region together contribute around 13% of the country's GDP.

3.3. Objectives of PES programs

All PES programs have one or more clear objectives, most of them related to water services. The objectives focus mainly on increasing water discharge (91.25%) and water quality (85.00%). The following most frequent objectives are vegetation increase (43.75%), sediment reduction (36.25%), and socioeconomic improvements (21.25%) (Fig. 3).

The focus on water PES programs is justified mainly by the need to supply the municipalities that are being compromised by the silting of the rivers. Furthermore, about 32% of Brazil's water is used for agriculture (Getirana, 2016). Vegetation increase is also in great part related to water services, that is, a portion of 37.50% of the programs that aim at improving water discharge also cited the increase vegetation as one of their objectives (Table S2, Supplementary material). The recovery of the watershed vegetation, specially around river springs and riparian forests (defined as Permanent Preservation Areas – APPs, established by the Brazilian Forest Code; Brasil, 2012), increases soil retention capacity, which in turn contributes to improving water quality and discharge through the sediment reduction (Jiang et al., 2019; Zhang et al., 2019; Zhang & Shangguan, 2018). The strategy of conserving native terrestrial ecosystems to enhance hydrological services has also been

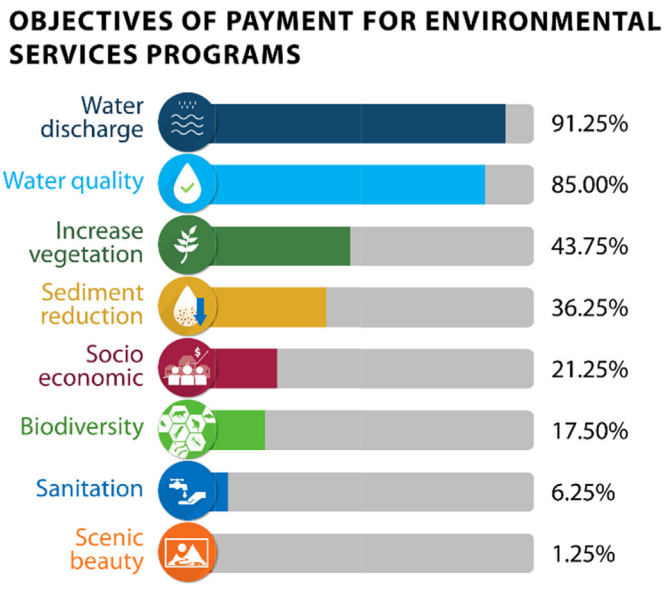

Fig. 3. Objectives declared by 100% of the programs.

observed in China (Liu et al., 2019; Wen et al., 2019), Colombia (Moros et al., 2020), and Costa Rica (Arriagada et al., 2012).

Socioeconomic objectives are pursued by 21.25% of the programs. Although the other objectives may bring indirect socioeconomic benefits, socioeconomic objectives are related to activities that directly improve community livelihoods by increasing income. The project Water Producer in Rio Branco– AC, for instance, promotes the participation of rural producers in the State Certification Program for Family Productive Units in Acre (Rando et al., 2014). This certification aims at income generation through sustainable production and insertion of rural producers in public lines of credit, financing, and funding. Other examples are Ibirapitanga Water Producer project, which aims to increase rural landowners' income (Moreira, 2018), and the Descoberto-MG Water Producer project, which intends to promote the environmental adequacy and regularization of rural properties.

Even though socioeconomic was not considered an objective, the "Social and Environmental Development of Rural Family Production Program" (Proambiente) was designed in the context of a series of popular protests in search of a less excluding system for family farming (Oliveira & Altafin, 2008). Implemented in 2003 in the Legal Amazon, the program benefited 4214 families with technical support and training (despite only 5 out of 12 projected poles, including 1768 families, received payment for ecosystem services). The program ended four years after its inception, when the Brazilian Government canceled the transfer of federal funds to the program, mainly due to the lack of specific legislation, as pointed by Oliveira and Altafin (2008).

Following the Proambiente program, the *Bolsa Floresta* program was created to serve more than 35,000 people in an extensive area of 10 million hectares in the Amazon, becoming one of the largest PES programs in the world (Viana et al., 2012). Bolsa Floresta operates in in the state of Amazonas, and has been of relevant importance to small landowners – which occupy a large part of the Amazon – by providing technical assistance and access to production technology and markets, helping them better align production practices with local opportunities, in addition to the increase in family income, the improvement of livelihoods, and to reducing the pressure of deforestation (Stabile et al., 2020).

While most of the projects focus on water services, six projects (7.50%) claim not to identify themselves as water PES, namely Bolsa

Floresta - AM, Bolsa Verde - MG, Reservas Particulares do Patrimônio Natural - PR, Conexão Mata Atlântica - RJ, Corredores Ecológicos Timbó e Chapecó – SC, and Corredores do Vale – SP. These projects focus mainly on the protection of biodiversity and the recovery of native vegetation in Conservation Units (Unidades de Conservação in Portuguese, UCs) and ecological corridors. UCs are specially protected spaces with the objective of conserving and protecting national biodiversity, while the ecological corridors guarantee the maintenance of ecological processes in the areas that connect UCs (Brasil, 2000).

Concerning the maintenance of scenic beauty, only the project "PSA Uso Múltiplo dos Rios Cênicos Formoso e Prata" mentioned it as an objective. Although the landscape is likely to improve if other objectives are achieved, the economy in the region of the cited project is strongly driven by tourism (Xavier, 2011), which may explain the focus on maintenance of scenic beauty.

Despite the lack of access to sanitation by most rural communities in Brazil, the objective of sanitation improvements was mentioned by only five projects (6.25%). To exemplify the reality of sanitation in rural communities in Brazil, 59.50% of inhabitants of rural areas in Brazil do not have access to adequate water supply, 79.40% to adequate sanitary sewer, and 76.40% to solid-waste management (Funasa, 2019, p. 260). Inadequate sanitation practices are persistent in the rural areas, where rudimentary cesspits are the most common method for sewage disposal, and solid waste is burned (Funasa, 2019, p. 260). The risk of polluting water resources should encourage Water Producer projects to adhere to environmental sanitation practices, once most of the areas within the scope of the program are destined for water supply to municipalities. Furthermore, the Water Producer program provides the construction of septic tanks (ANA, 2018). Considering the lack of sanitation affects the most socially vulnerable communities (CadÚnico, 2019), this may reflect the weak influence of the poor in PES schemes in Brazil.

Bremer et al. (2016) took a survey of the goals and strategies of 16 existing programs associated with the Latin American Water Funds Partnership (LAWFP) in 2016, five of which were in Brazil. The authors report that the stated objectives were mainly related to water quality (94%) and quantity (87%). According to the survey, 56.25% and 68.75% of Latin American PES programs strived for co-benefits to local livelihoods and biodiversity, respectively, a different trend from what we found for Brazil (21.25% and 17.50% for socioeconomic and biodiversity benefits). Sediment reduction goal was also more frequent for LAWFP, with 11 out of 16 programs (68.75%). According to their study, Brazilian programs were more engaged in revegetation efforts than other programs, ascribed to compliance with the Brazilian Law. This can be seen in the Atlantic Forest, where a great part of the management area of the Water-PES programs is destined for the conservation of the remaining areas of forest, which are protected by the Law of the Atlantic Forest (Taffarello et al., 2017).

3.4. Activities of PES programs

Most projects report the implementation of more than one conservation activity (94.52%). The most common conservation activities are revegetation by planting seedlings or natural regeneration (83.56%), and fencing of APPs (83.56%) (Fig. 4). The practice of fencing APPs supports the revegetation, as it enhances the development and maintenance of native seedlings by preventing trampling by cattle. Coincidentally, the number of projects that adhered to these two activities is the same, however, the projects are not necessarily the same, as the common share of these activities is 90.16% (see Table S2, Supplementary material).

The restoration and maintenance of native vegetation provide the regularization of rural properties, as the Law for the Protection of Native Vegetation (NVPL), also known as the "Forest Code" (Law No. Native Vegetation and one of its requirements is the obligation to recompose native vegetation in APPs along watercourses). Effective compliance with the LPVN is essential to recover the forests that were eliminated from the protected areas of rural properties and provide for the preservation of what remains of the flora, since 53% of the remaining native vegetation in the country is found on private rural properties, and not within conservation units (Soares-Filho et al., 2014).

There is an abrupt decline in the ecological integrity of communities of various animal groups when the proportion of native vegetation in a region drops (Pardini et al., 2010, Ochoa-Quintero et al., 2015). Furthermore, the reduction of habitats has been the main factor associated with the extinction of species in the country (Ribeiro & Freitas, 2014). Therefore, these conservation measures are also important for maintaining biodiversity, as well as for providing other ecosystem services, such as soil protection, climate regulation, and generation of water resources (Trevisan et al., 2020; Ferreira & Valdujo, 2014). Agricultural crops also benefit from these practices, as they are more productive near remnants of native vegetation, as several species of animals, plants and microorganisms act in the biological control of pests (Silva et al., 2012).

Soil and water conservation practices are adopted by 52.05% of the respondent projects, including building level terraces, livestock management, reduction of fire use, no-till farming, containment of gullies, soil preparation, contour farming, among other preventive techniques. These practices aim to control erosion and reduce the sediment concentration in water bodies (Pavei et al., 2021). Another measure adopted for this purpose is the incorporation of dirt road management (46.58%), including the construction of road embankments, roadbeds, gravel roads and construction of drainage systems for water abstraction along the roads.

Only 12 of the respondent projects (17.81%) have cited environmental education and 13 mentioned rural wastewater services as an activity adopted. The fact that the minority of programs conduct some form of environmental education can cause programs to fail, as the provision and maintenance of ES through PES schemes depend on having relevant stakeholders fully informed and aware of the importance of the schemes (Canova et al., 2019). Environmental education is also a key factor for promoting adherence and enrollment of landowners, as negatively experienced by the Pipiripau Water Producer project (Lima & Ramos, 2018). Trust and participation in the design of the scheme also play a crucial role in determining participation in PES schemes (Zanella et al., 2014).

Four of the respondent projects listed all activity options as strategies to achieve sustainable production and environment improvements, namely Produtor de Água no Pipiripau-GO, Produtores de Água Rio Verde-GO, Conservador das Águas-MG, and Guardião dos Igarapés-MG) (Table S3, Supplementary material).

3.5. Monitoring of activities implemented by PES programs

Concerning monitoring activities, 44 programs (55.00%) provided information (Table S4, Supplementary material). Most of them monitor more than one environmental indicator: 38.64% of respondents monitor water quality, 25.00% monitor water discharge, 18.04% soil loss, 18.04% vegetation cover, 6.82% have a rain gauge, 6.82% monitor biodiversity, 9.09% do not specify the type of monitoring carried out, and 40.91% do not monitor any indicator.

Our results show that most Brazilian PES programs still lack monitoring strategies, with the main criteria and indicators to be evaluated. In addition, most of the basins in which the projects are implemented do not have monitoring records, which makes it

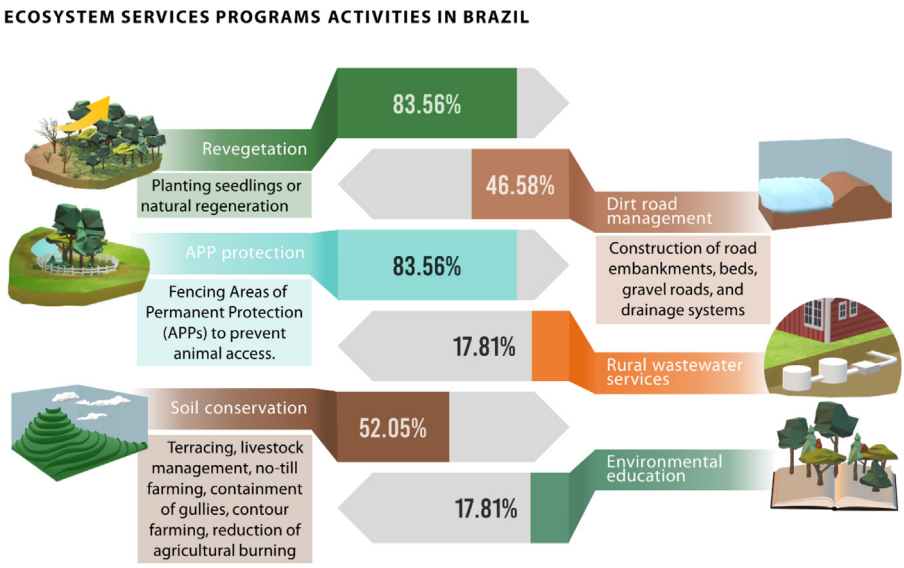

Fig. 4. Conservation practices declared by 73 investigated projects (91,25%). Revegetation and fencing of APPs are the most common practices, applied by 83.56% of the projects, followed by soil conservation practices, dirt road management, rural wastewater services and environmental education.

difficult to assess the performance of the conservation measures adopted by comparing them with historical timeseries. Thus, in addition to routine monitoring, which involves evaluating the behavior of streamflow and water quality, it is important to monitor the structures implemented, such as evaluating the volume of water captured per km of terrace or per unit of infiltration basin.

The validation and dissemination of hydrological services resulting from land management actions are essential to prove the effectiveness of PES projects. In addition, this approach can increase public awareness, as well as serve as experience in developing new programs and increasing funding.

3.6. Funding and collaborators

We obtained response from 76 or 95.00% of the programs about their funding sources. Most of them have more than one source (Table S5, Supplementary material). We found that all programs receive funding from at least one public institution, 90.79% of the respondent programs receive funds from municipal governments, 76.32% from the ANA, 50.00% from State Governments, and 42.11% from NGOs. Private companies fund 31.58% of the respondent programs (Fig. 5).

The largest fundings are invested in the state of Espírito Santo, with US$ 20,147,518.64, followed by Rio de Janeiro with US$17,035,648.30, Amazonas with US$ 6,352,061.52, Minas Gerais with US$ 5,508,793.50, São Paulo with US$3,561,571.94, and Goiás with US$ 1,413,498.07 (Fig. 6a). These values add up to more than 96% of the total amount invested in Brazil found in our study. The Atlantic Forest biome covers all the territory of Espírito Santo and Rio de Janeiro States, also occurring in most of the state of São Paulo, and in the states of Minas Gerais and Goiás. Consequently, the largest amount of funding is accrued in this biome (Fig. 6b). The remaining amount is invested in the states of Mato Grosso do Sul, Paraná, Mato Grosso, Santa Catarina, Bahia, Pará, Tocantins, Rio Grande do Sul, and Acre, each of them receiving less than a million dollars.

Despite ANA's high funding in projects, payment itself is made by partners previously defined within the scope of the project's organizational arrangement. It was found that most program partners also are public departments. While public funding is fundamental to mobilize funds for water resources, we observe a discontinuity in several programs, likely due to the changes in federal and state policies and budgets over the years. The integrated support between public, private and non-governmental organizations is a promising alternative to guarantee the continuity of payments and the renewal of contracts, providing better planning, management, transparency, and financial sustainability. For instance, the Baudducco food industry, which supports the Extrema project, to compensate for the use of water in its food production, and third sector institutions, such as The Nature Conservancy (TNC), The Grupo Boticário Foundation for Nature Protection, SOS Mata Atlântica and the World Wide Fund for Nature (WWF) that demonstrate how the third sector can act proactively to achieve results. Following the “user pays” and “provider gets” principles, private sector entities (companies, associations, associations, etc.) can participate in PES public policies as users benefiting from ecosystem services, provided by the owner owners. The private sector can also assume the important role of: (i) co-financier with the Government; and (ii) financer and inducer of environmental asset markets.

Sanitation and electricity companies have great potential to become buyers of environmental services. Sanitation companies are benefited from the increased life cycle of their plants due to the increase in water supply, and the reduction of treatment costs due to the improving water quality. Electricity companies are also benefited from the increased water supply for power generation - considering that hydropower represents 65% of the Brazilian electrical matrix (EPE, 2021) - and the increased life of reservoirs due to the reduction of sedimentation processes (Geluda & Young, 2014). In Brazil, sanitation and electricity companies, as well as industry, irrigation consumers, and any other water abstraction use, are subject to pay charges for water use.

The charge for the water uses in Brazil is a legal instrument based on the idea that water is a public good, and a limited natural resource with economic value. River basin committees are responsible for promoting debate among the basin users and establishing the mechanisms of charging for water use. The charging should not be interpreted as a tax, but as a compensation for the use of a public good. To date, there are six basins owned by the Brazilian government that charge for water: *Bacia do Rio Paraíba*

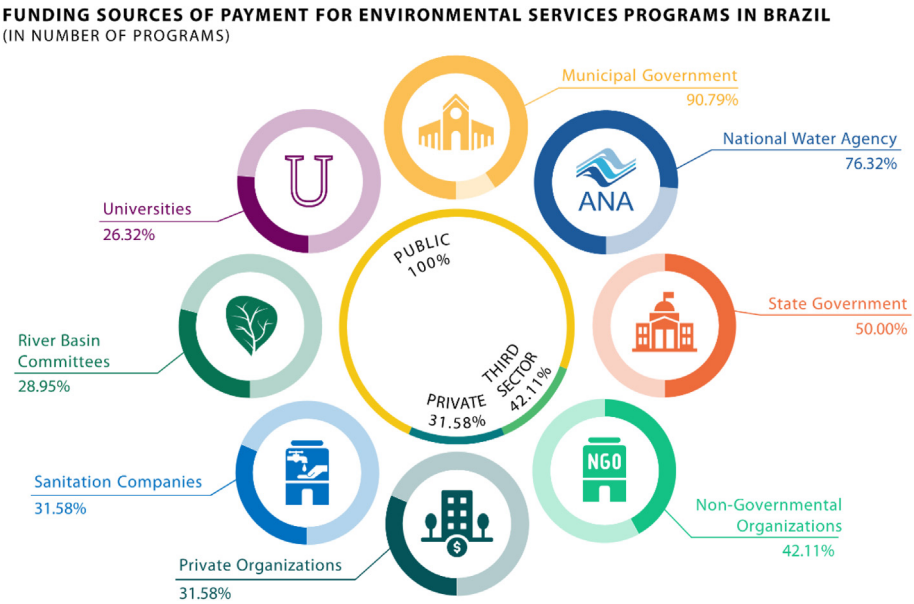

Fig. 5. Funding sources and partners declared by 95% of the Payments for Ecosystem Services (PES) programs in Brazil. All programs receive funding from at least one public institution.

do Sul, *Bacias dos Rios Piracicaba, Capivari e Jundiaí* (PCJ), *Bacia do Rio São Francisco*, *Bacia do Rio Doce*, *Bacia do Rio Paranaíba* and *Bacia do Rio Verde Grande*. In addition to these basins, water charging has already been implemented at the state level in all basins of Rio de Janeiro and Paraíba, and partially in the states of São Paulo, Minas Gerais, Paraná, and Ceará (ANA, 2022).

Since the first initiative, 883 million dollars have been collected from water charging, adding up national and state-owned basins (ANA, 2022). Part of the collected amount could be transferred to PES initiatives within the basin, as already occurs in the Water Producer Program in the PCJ, as charging for the use of water can represent a financial source that ensures, in an uninterrupted way, the maintenance of PES projects. Therefore, it is necessary to overcome the bureaucratic and hierarchical difficulties of including PES projects in the Water Resources Plans, with the aim of benefiting medium and small landowners. Since the resources from water charging are transferred to the user sectors for the funding of projects previously ranked by the basin committees. It is in this context that PES programs work, seeking to demonstrate that the need for water is real and, although rural producers are subject to maintaining sustainable land management in order to improve water in terms of quality and quantity, the costs for providing this good need to be shared among all users.

3.7. Evidence of positive impacts of payment programs for environmental services

The representative of the program Water Producer in Pipiripau – DF reported that they noticed very positive results regarding the increase in vegetation cover, restoration of roads, soil conservation, and increase in the quality and quantity of water. Strauch et al. (2013) found evidence in this basin that corroborate to these informal findings. The authors show that the implementation of conservation measures, mainly level terraces and sediment containment basins, resulted in reductions of up to 40% in the sediment load. In Brazil, the economic impact of erosion on crops is estimated at about 1.3 billion dollars annually, caused by a loss of approximately 617 million tons of soil (Dechen et al., 2015). This problem occurs due to the absence of adequate management techniques and adherence to the program can also contribute to cost reduction as a result of soil loss.

In the Produtor de Água program in Rio Verde - GO, the isolation of spring areas and the removal of disturbance factors were able to promote the regeneration of local vegetation, promoting an increase of 5.60% of preserved springs and 7.40% of regenerating springs in 3 years (Pereira & Ferreira, 2012; Merida, 2014). Considering the increase in vegetation, another project installed in the Goiás state (municipality of João Leite) also observed benefits such as the increase in biodiversity, attracting diverse species of birds to the place, which in turn, started to bring new seeds that helped in ecological restoration (Jaime & Peixoto, 2018). Although increasing biodiversity is not a direct objective of this program, we can note the importance of biodiversity in achieving the restoration of vegetation that is desired by them.

Implementing soil and water conservation practices in the Salto sub-basin, located in Extrema-MG, provided improvements in the water quantity and quality. In this area, the following was carried out: 19.7 km of road readjustments; 1020 water catchment basins and inlet channels; 118 ha of channel terraces, and 2.4 km of slope correction (ANA, 2020); 1,554,793 seedlings planted and maintained, and 276,811 m of fences within the scope of the Conservador das Águas Project (Pereira, 2017). As a result, there was an increase of around 60% in forest cover and generation of carbon credits (Richards et al., 2015).

Currently, the Conservador das Águas Project is a PES project model, it is already well established with its consolidated actions, credibility in Extrema society and among farmers and partners. The first beneficiaries were the inhabitants of Extrema, as the project began upstream from the municipality's water catchment point, was well accepted by society with manifestations in the local press, at the Municipal Environmental Development Council and a motion by the City Council (Pagiola et al., 2013). According to the authors, the project has a team capable of managing the program and carrying out the environmental restoration, resulting in the generation of more than 30 direct jobs.

The Manancial Vivo project implemented in the municipality of Campo Grande - MS in the Guariroba Environmental Protection Area promoted the recovery of riparian forest covering an area of

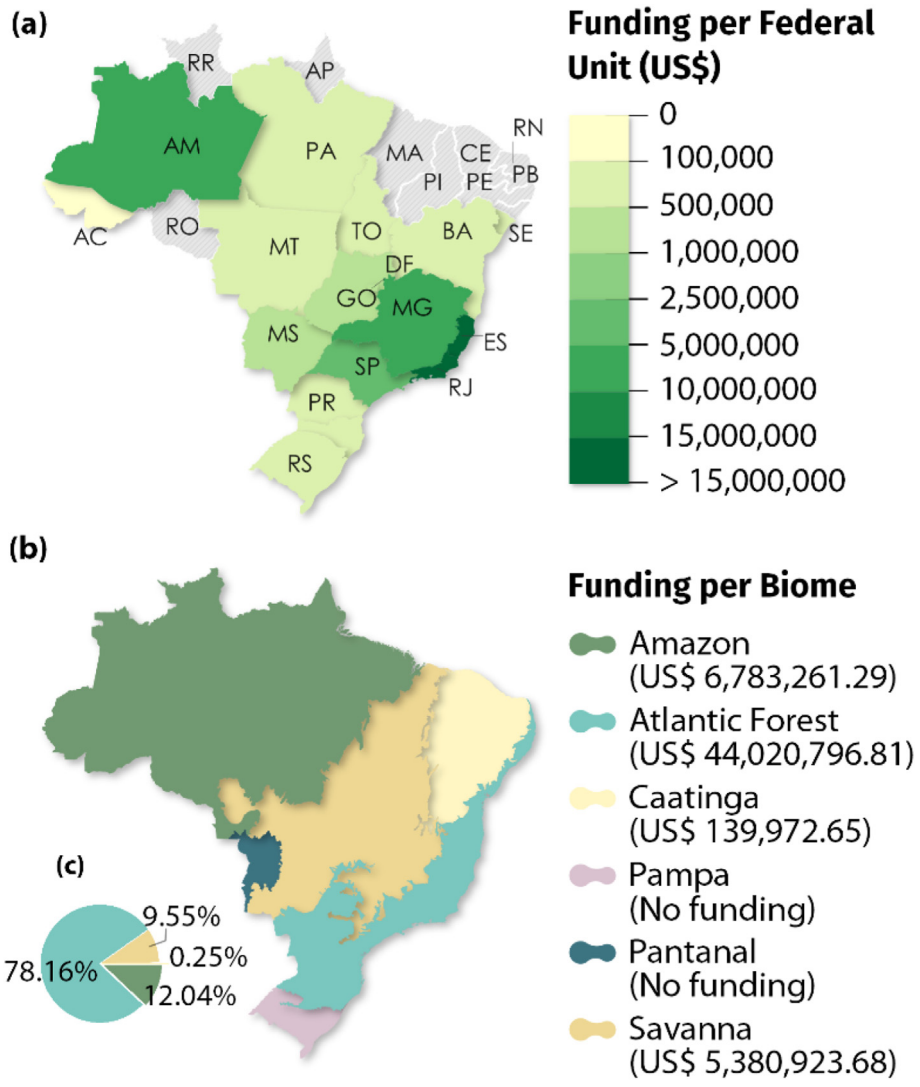

Fig. 6. (a) Funding in Payments for Ecosystem Services (PES) Programs by state in Brazil. The largest investments are concentrated in ES, RJ, MG, SP, and GO. Each of the remaining states receive less than a million dollars. (b) Funding in Payments for Ecosystem Services (PES) Programs by biome in Brazil. States: AC – Acre; AL – Alagoas; AM – Amazonas; AP – Amapá; BA – Bahia; CE – Ceará; DF – Distrito Federal; ES – Espírito Santo; GO – Goiás; MA – Maranhã; MG – Minas Gerais; MT – Mato Grosso; MS – Mato Grosso do Sul; PA – Pará; PB – Paraíba; PR – Paraná; PE – Pernambuco; PI – Piauí; RJ – Rio de Janeiro; RN – Rio Grande do Norte; RS – Rio Grande do Sul; RO – Rondônia; RR – Roraima; SC – Santa Catarina; SE – Sergipe; SP – São Paulo; TO – Tocantins.

227.5 ha, which represents 2% of the Alto-Guariroba and Saltinho sub-basins (Sone et al., 2019). The area of the slope terraces was also expanded, environmental education, road repairs and building "barraginhas" (small dams for no-pavement road drainage). The authors state that these measures provided a significant reduction in soil loss from 2.35 to 1.78 tonnes ha-1 yr-1 (approximately 25%). Thus, there was an increase in the base flow of 73% in the middle section and 41% in the lower cross-section until 2014, when about 45% of the total practices were carried out. This basin is the main source of water, as it supplies about 50% of the total water consumed by the urban area of the municipality (Sone et al., 2019). In this way, the project contributes to the solution of the water supply problem of city, which was being caused by the degradation of the Guariroba system through the silting of water bodies and the reservoir, which resulted in the need to expand the capture system through deep wells distributed throughout the urban area. This emergency measure contributes to progressive and expressive readjustments in the tariffs of sanitation services provided to the population of Campo Grande, in addition to compromising the productive capacity of properties in the basin (Pagiola et al., 2013). Therefore, society has benefited from these results, as well as rural landowners who depend on this resource to maintain their activities.

Significant improvements in water quality were observed from a physical, chemical, and microbiological point of view by the program "Produtor de Água Vera Cruz– RS" (Oliveira et al., 2014), besides soil stabilization, reducing erosion processes, and an increase in floristic composition from the stabilization of forest strata (Delevati et al., 2018). The Water Producer program in São José dos Campos-SP also noticed improvements in water quality, mainly regarding the reduction of turbidity (Fiore et al., 2017), which can lead to a reduction in water treatment costs for the municipality's basic sanitation company.

The Proambiente program validated the importance of environmental education, as through the training and technical assistance offered, there was a relevant contribution to the improvement of productive techniques, such as the replacement of the burning system during the planting phase (Oliveira & Altafin,

2008). The relevance of environmental education in training the population and raising awareness about the protection of natural resources was also observed in the São João-RJ project (Guedes & Seehusen, 2011).

Proambiente program is still ongoing and is considered an example of the effectiveness of municipal initiatives, considered one of the world's best practices by the Dubai International Award for Best Practices in 2012 (UN-HABITAT, 2012). Persistence in encouraging enrollment resulted in 53 contracts in the Posses sub-basin, almost half of the existing landowners in the sub-basin, covering 90% of the land area (Gonçalves, 2013). During its execution period, Proambiente achieved great results in reducing deforestation, burning agriculture, and agrochemicals use, as reported by Almeida et al. (2013). The main legacy was the social initiative and experience in sustainable production and forest conservation in the Amazon, which drew the attention of Brazil's government officials to the need for a PES national policy (Borner et al., 2007).

3.8. The Brazilian National Policy on Payments for Environmental Services

The Brazilian Federal Constitution imposes the duty to defend and preserve the environment for present and future generations on the Government and the community. Punitive legal instruments have been adopted for the collectivity to contribute to environmental preservation in a participatory way, but were not able to mitigate sufficiently the advance of environmental degradation. In this context, PES came up and these legal instruments are no longer the only means of social guidance to encourage environmental conservation.

Until January 2021, there was no specific national legislation for the implementation of PES programs, so municipal, state and even national initiatives were implemented independently, causing a great heterogeneity of policies PES. Law 14.119 came into force after a long legislative process, establishing the National Policy on Payments for Environmental Services (in Portuguese, *Política Nacional de Pagamentos por Serviços Ambientais* - PNPSA). The Law defined concepts, objectives, guidelines, actions, and criteria for implementing the PNPSA (Brasil, 2021).

PNPSA defines payment for environmental services as a voluntary transaction, through which a payer of environmental services transfers financial resources or other form of remuneration to a provider of these services, under agreed conditions, respecting legal provisions and regulations. PNPSA categorizes ecosystem services as provision, support, regulatory and cultural, expanding the possibilities of PES, as the previous initiatives in the country were mainly aimed at provision services, in particular the provision of water resources.

The law also clarifies that ecosystem services can be used for maintenance, recovery or improvement of environmental conditions, directly relating to the general objectives of the Brazilian National Environmental Policy. In this way, PNPSA establishes a structure to operationalize and encourage the PES market, leading to a scenario of greater legal certainty for existing programs and for those to be implemented.

3.9. Obstacles and challenges of PES in Brazil

Robust monitoring protocols need to be established through, for example, periodic inspections of registered lands or remote observations of vegetation cover changes by satellite imagery, among other methods. Monitoring data, in addition to allowing the perception of results, can also be used in the formulation of sanctions and their application (for example, cancellation of contracts and reimbursement of payment) when ecosystem service (ES) providers breach the terms of the contract.

The involvement of the academic community is desirable, as in addition to validating and qualifying ongoing monitoring protocols, they can also provide long-term follow-up by providing a baseline regarding water quality and quantity. Furthermore, monitoring is a key aspect for adaptive management interventions if revegetation problems have been identified, increasing the efficiency of the restoration process. As an example of the effective participation of universities, we can cite the Conservador das Águas de Extrema project, which, through scientific research that has been and is being carried out, expanded the potential of decision-making both in planning and execution, increasingly guiding the way development of actions and assimilation of new technologies (Pagiola et al., 2013).

The poor distribution of programs across the country is also a relevant issue, as it is often influenced mainly by economic power and does not necessarily consider local needs. As a result, we perceive unreached biomes with different needs, such as the Pantanal, which needs programs aimed mainly at protecting biodiversity. However, consistent demand is unlikely to arise voluntarily for PES programs that aim to increase biodiversity, as the community is not directly benefited, as they are with water programs. Therefore, the government has a key role in this process of creating demand or markets, and can assume the role of buyer of environmental services.

To achieve better distribution of programs throughout the Brazilian territory, a decision support tool should be developed, involving all the criteria established in the National Policy on Payments for Environmental Services to facilitate the definition of priority areas for the implementation of projects both at the micro and macro basin levels. In addition, as in most cases the initiatives/projects start in municipal governments, it is recommended to promote partnerships between municipalities so that there is an exchange of experiences between those at different stages of implementation.

Another important issue is the implementation and maintenance costs of the programs, which are very variable, with funding ranging from US$ 3496.00 to US$ 19,780,000.00. These amounts, most of the time, not only reflect expenses associated with payments to rural producers, but also forest restoration and conservation inputs (fences, seedlings, fertilizers, etc.), labor, as well as inputs for soil conservation, rural sanitation systems, and road maintenance. The high transaction costs for the establishment of projects are often not considered, resulting from the need to consolidate partnerships and also the still pioneering nature of the initiatives. Thus, the programs have difficulty in keeping payments active and in renewing contracts. Ideally, the resources and means for a future renewal of PES contracts must be planned even in the very project design.

Greater participation by the private sector is an alternative, but for this, the potential buyers must be convinced that the actions proposed by the programs are the best way to provide water in quality and quantity. Therefore, seminars and mobilization initiatives are recommended, with focus on potential payers (basin committee members, large users) and opinion-makers in the private industrial sector. The participation of the basin committees is also desired to stimulate the implementation of charging for the use of water where it has not yet been implemented. In addition, to attract new partners, it is also suggested that the ANA platform be used properly, feeding it frequently with PES details and results, and that educational materials on PES be made available.

The instability of payments also increases the uncertainties for the participation of the participants, as well as the required bureaucracy. For example, the long-term contracts and obligations for landowners. In general, contracts with rural landowners have a

maximum duration of 5 years, except for the Water Producer in Guaratinguetá, which can last up to 10 years, and the Proambiente program, which lasts for 15 years, and may be renewed (Table S1, Supplementary material).

However long-term agreements may be more vulnerable to changes arising from external factors such as, for example, the emergence of new technologies, policies or changes in economic conditions in general. According to the experiences evaluated by Wunder et al. (2008), a period of five years has typically been shown to be a good practical solution, considering the inevitable commitment related to flexibility, stability and transaction costs involved in the development of contracts.

On the other hand, environmental education and training programs demonstrate positive effects, boosting participation and the environmental performance of the programs. This fact demonstrates the need for a broad training process encompassing dissemination and exchange of information, so that, in addition to enabling the implementation of proposed measures, the importance of the forest-water relationship is strengthened in society. Regarding the dissemination process, it is important to make clear that participants have other benefits in addition to the payment itself, such as the application of the Forest Code, mapping their territory, the conservation of soils, forest, and water resources. Furthermore, in some cases, the implementation of sanitary measures (such as the implementation of septic tanks), diversifying sources of income, improvements in management practices and valuing rural property.

We also highlight the need for Brazilian PES to address social goals, focusing on equitable access to payments (Bremer et al., 2014; Lliso et al., 2020; Robinson et al., 2016). Proambiente was one of the only Brazilian PES programs that included, in addition to farmers, indigenous people and fishers (Oliveira & Altafin, 2008). Most Brazilian PES programs have registered only farmers or settlers, as can be seen on the ANA website (ANA, 2020). Caution should be taken not to create greater social inequity due to the PES implementation, especially when corrupt or unstable governance may exacerbate deforestation because of unenforced laws or undefined property rights and land tenure (Plumb et al., 2012). Particularly in Brazil, where deforestation on indigenous lands was less than 2%, while the average level in the same period in the Amazon was 19% (IPAM, 2015), indigenous communities demonstrate their conservationist essence by the direct links between cultural and environmental services.

Experiences in other countries have demonstrated the benefits of including the perspectives of indigenous peoples in PES schemes, who have previously rejected these schemes for their design process or power asymmetries, due to socio-environmental conflicts (Lliso et al., 2020). As pointed by Plumb et al. (2012), participatory planning in PES brings potential indirect benefits such as improvements in access to education, a reduction in infant mortality rates, and healthcare, while improving land management practices and reducing emissions. In addition, the participants are also favored by improvements in planting, regularization of the property in relation to the environmental code, and the increased monetary value attributed to the property (Paiva & Coelho, 2015).

The lack of transparency is also a major challenge. Although it is one of the main PES initiatives in Brazil, to obtain information on ANA's Water Producer projects has been challenging. In fact, there is a platform designed to aggregate information about these projects, however, there is a lack of communication between the managers of the different projects and between sectors of the governmental structure, making data collection difficult. Information could be aggregated through insertion into the ANA platform, or through an annual event where managers discuss data and exchange experiences.

4. Conclusions

This paper is an important step toward understanding PES programs in Brazil, a field that has been gaining prominence in recent years in science and society. We identified the main advances and knowledge gaps of PES schemes in Brazil. Although the country has a significant number of programs, the distribution is uneven between biomes and states. We identify there is a need to include Pampa, Pantanal, and Caatinga biomes in PES schemes. The main sources of funds for the programs are municipal governments and the Brazilian National Water Agency (ANA).

The lack of transparency is a major limitation for capturing the actual scenario of investors' contribution, although good results are expected from the recent implementation of a National policy for regulating PES in Brazil. The poor distribution of resources between states and inactive payments call for the inclusion of private partners, leading Brazilian PES schemes to rely more on free-market mechanisms. To date, while most schemes focus on water services, socioeconomic, sanitation and biodiversity issues are placed in background. Including the most socially vulnerable rural groups in PES schemes offers an opportunity to not only improve environmental conservation, but also to reduce social inequality in Brazil.

Many of PES programs have already had important positive impacts in restoring the environment in Brazil, in addition to improvements in cultivation and increasing the market value of properties. We demonstrate that most Brazilian PES still fail in the feedback by the lack monitoring strategies. Feedback is key for validating the implemented actions, for communities to capture the value of ecosystem services and for encouraging PES participation and development, in addition to attracting investors and partners from different segments. For this, PES programs' results and data must be widely spread and easily available to farmers, stakeholders, and society.

The rural sector in Brazil has an enormous capacity to contribute to the conservation of ecosystems, for which payment for environmental services poses a powerful tool. Therefore, limitations such as the lack of transparency, lack of monitoring, social inequality and poor distribution must be overcome. In view of the positive effects resulting from PES experiences, the rapid expansion of programs and the well-known ecosystem richness, Brazil is fertile ground for the growing PES efforts.

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.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.iswcr.2023.01.001.

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