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ECOSYSTEMS

Relationship between Payment for Ecosystem Services Programs and Disasters in Southeast Atlantic Forest region, Brazil

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Abstract: Ecosystem services significantly contribute to ecosystems resilience and stability. In this sense, payment for ecosystem services can be designed and applied to prevent or decrease environmental disaster risks. This study aimed at verifying whether municipalities taking part in PES programs present higher number of natural disasters (flood, drought, landslide and fire) between 2009 and 2020 in the Paraíba do Sul river basin. We expected that municipalities having more disaster events would take part in more projects, which we found. Programs can be implemented in response to the increase in natural disasters. We also expected PES calls to explicitly target natural disaster prevention measures and actions, which we did not observe. We found actions related to soil conservation and vegetation cover that might prevent risks, but there were no mentions of disasters. It is concerning that PES in Vale do Paraíba Paulista programs have not been addressing natural disaster risk reduction in a landscape, where floods, droughts, anthropogenic fires and erosion problems associated with hilly reliefs have been increasing in the last years.

Key words: Conservation, nature-based solutions, natural hazard, restoration, risk.

INTRODUCTION

In the last 60 years, natural disasters (here disasters triggered by natural hazards that cause, in addition to human deaths, severe economic losses, destruction of housing, infrastructure and environment: Middelmann & Middlemann 2007) have increased around the world. Between 1960 and 2019, a 14-fold increase in annual disasters, from 44 in 1960 to 611 in 2019, causing environmental, social and economic losses, were observed (Chen et al. 2021). A special report from the Intergovernmental Panel on Climate Change (IPCC) shows that vulnerability to disasters such as desertification, floods, fires and landslides, issues addressed in this article, come from an unplanned territorial occupation and increasing urbanization (IPCC 2019). Damage to ecosystem stability and resilience directly affects intensity, frequency and duration of extreme events (Dey & Lewis 2021). In Brazil, although extreme natural events have been recurrent since the 16th century, with landslides in Rio de Janeiro hills (Sternberg 1949, Jones 1973), public policies related to disasters are very recent, dating from the 1990s, with the main focus on mitigation and not prevention (Silva et al. 2016). The National Policy on Civil Defense (Law 12.608/2012, Brasil 2012), is known to be the first federal law to prioritize disaster reduction risk and prevention over help and assistance to affected population. From 1991 to 2020, Brazil has been severely affected by natural hazards, especially droughts, fires and floods (as can be seen in Figure 1).

The Sendai Framework for Disasters Risk Reduction 2015-2030 seeks to understand disaster risks and to strengthen investments

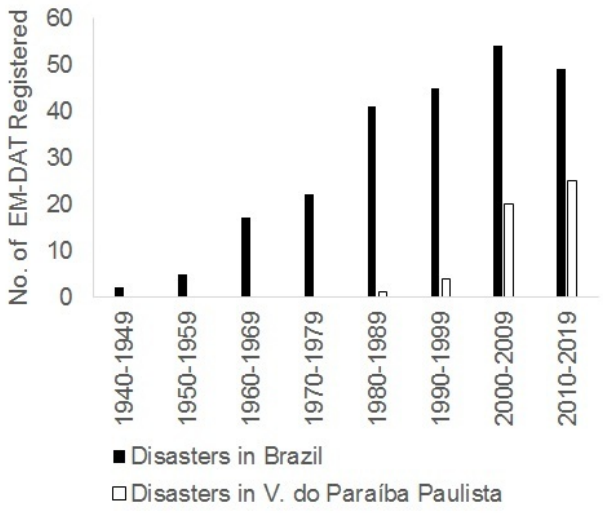

Figure 1. Natural Disasters in Brazil and in Vale do Paraíba Paulista, Brazil, registered in EM-DAT.

in prevention and resilience, reducing losses of life, livelihoods and economic and environmental assets, mainly (UNDRR 2015). Regarding environmental assets, ecosystem services include a multitude of benefits to humans and are related to provision, regulation, cultural and support services (MEA 2005), which are (i) provision: obtained directly from ecosystems, providing food, water, energy and raw material; (ii) regulation: ability to regulate natural processes that support species life, such as climate control and air purification by photosynthesis; (iii) information and cultural: intangible, personal or collective, referring to recreational, educational, aesthetic or spiritual; (iv) habitat or support: allows continuity of the above, maintaining genetic diversity and evolutionary processes, through nutrient cycling and soil formation, for example (De Groot et al. 2002). Ecosystem services, such as natural hazard regulation, significantly contribute to ecosystems' resilience and stability and might prevent or decrease environmental disaster risks.

To regulate ecosystem services provision, Payment for Environmental Services (PES) transfers financial resources from beneficiaries of certain environmental services to those who provide these services or are fiduciaries of environmental resources inferred (Mayrand & Paquin 2004, Aza et al. 2021). Wunder (2005) defines PES as direct financial payments to service providers, dealing with policies aimed at the provision of environmental services under their domain but reformulates its concept decentralizing the economic point of view and focusing on the political issue of PES, compensating ecosystem services and, by agreed rules, generating a desirable impact (Wunder 2015). The social function of PSA programs is, many times, more valued than the economic function, considering inert values of the human being, being able or not, consequently, to discuss PSA as a market mechanism (Muradian et al. 2010). PES programs can be designed and applied by the government or by Non-Governmental Organizations (NGOs) and, instead of punishment (as command and control environmental policies), bring benefits and incentives to the affected population and society (Aguilar-Goméz et al. 2020). According to Jones et al. 2020, in a systematic review, financial and non-financial motivators, including risk reduction, positively influences willingness to participate in PES programs in the Global South. In the Brazilian Atlantic Forest, risk reduction does not seem to be much important in farmers' choices regarding payment for ecosystem services programs (Alarcon et al. 2017).

Even with the increasing number of public and private PES projects in the world, such as in France, China and Brazil (Vaissière et al. 2020), there are still uncertainties related to the demonstration of real environmental benefits of PES (Lima et al. 2017). Studying PES programs, from the process of calling landowners, eligibility, enrollment to project final results, could help the scientific community, decision makers and managers to understand and fill the

gap of ecosystem services practical advantages to society, preventing monetary losses and inadequate environmental conservation and restoration (Aguilar-Goméz et al. 2020). If studies evaluating Brazilian PES programs are rare (Jones et al. 2020), even more scarce is research assessessing the role of specific ecosystem services in these programs, such as regulation services related to natural disaster prevention and mitigation (Munang et al. 2013, Unterberger & Olschewski 2021).

PES programs in Brazil are relatively new (discussed since 2007 and regulated since 2012, through the New Forest Code legislation: Lei 12.651/2012: Brasil 2012) and only in this year a National Policy on Payment for Environmental Services was approved (Lei 14.119/2021: Brasil 2021). Guedes and Seehusen 2011 systematized PES projects in the Brazilian Atlantic Forest biome (mainly in South and Southeast regions of the country, especially in São Paulo state) and found 78 PES projects; of which 33 were related to water, 40 to carbon and 5 to biodiversity. None of these projects directly or indirectly mentioned the willingness to prevent and mitigate disaster risks, although the main objective of PES program is not necessarily to reduce natural disasters. Instead, they seek for ecosystems conservation in order to generate ecosystem services and disaster prevention might be a positive indirect impact of their application. Despite that, in 2020, one of the heads of Environment Secretary of São Paulo state said that a large state PES project was built in response to a harsh flood that happened in 2010 in São Luiz do Paraitinga, a small municipality in that state (personal communication).

Thus, this study aimed at verifying the inclusion of regulating services (namely in this study, prevention of natural disasters) in the call notices (in Portuguese "editais") of PES programs developed in Southeast Atlantic Forest, Paraíba do Sul river basin region, and its relation with the number of natural disaster events (specifically flood, drought, landslides and fire). We expected that municipalities having more disaster events would participate in more PES projects in order to diminish these events. We also expected prevention of natural disasters to be mentioned in the PES call notices. This research is justified by the fact that it contributes to theoretical scientific investigations about PES programs and its possible impacts on disaster risk reduction that could bring social and environmental gains in a global environmental crisis context. The Paraíba do Sul River basin sits on the fringe between the major metropolitan areas of São Paulo and Rio de Janeiro (the biggest Brazilian cities). Although populous, the mostly rural valley is currently characterized by a patchy landscape of tropical forest remnants and pastures (Sapucci et al. 2021) and has become a focus for regeneration of the Atlantic Forest biome (Silva et al. 2016) and several restoration and conservation projects (observatorio-darestauracao.org.br), receiving significant amount of funds from national and international organizations. Besides all that, natural disasters, such as recurrent floods, droughts, an-thropogenic fires and erosion problems associated with hilly reliefs (INPE 2021, AGEVAP 2020) make the region of great relevance and need for studies relating PES projects and ecosystem services with the prevention of natural disaster events.

MATERIALS AND METHODS

Study site

The study is focused on Vale do Paraíba – São Paulo portion, inserted in the Paraíba do Sul river Basin and in "Vale do Paraíba e Litoral Norte" Metropolitan region, located in São Paulo state, Brazil (Figure 2). The region has 34 municipalities,

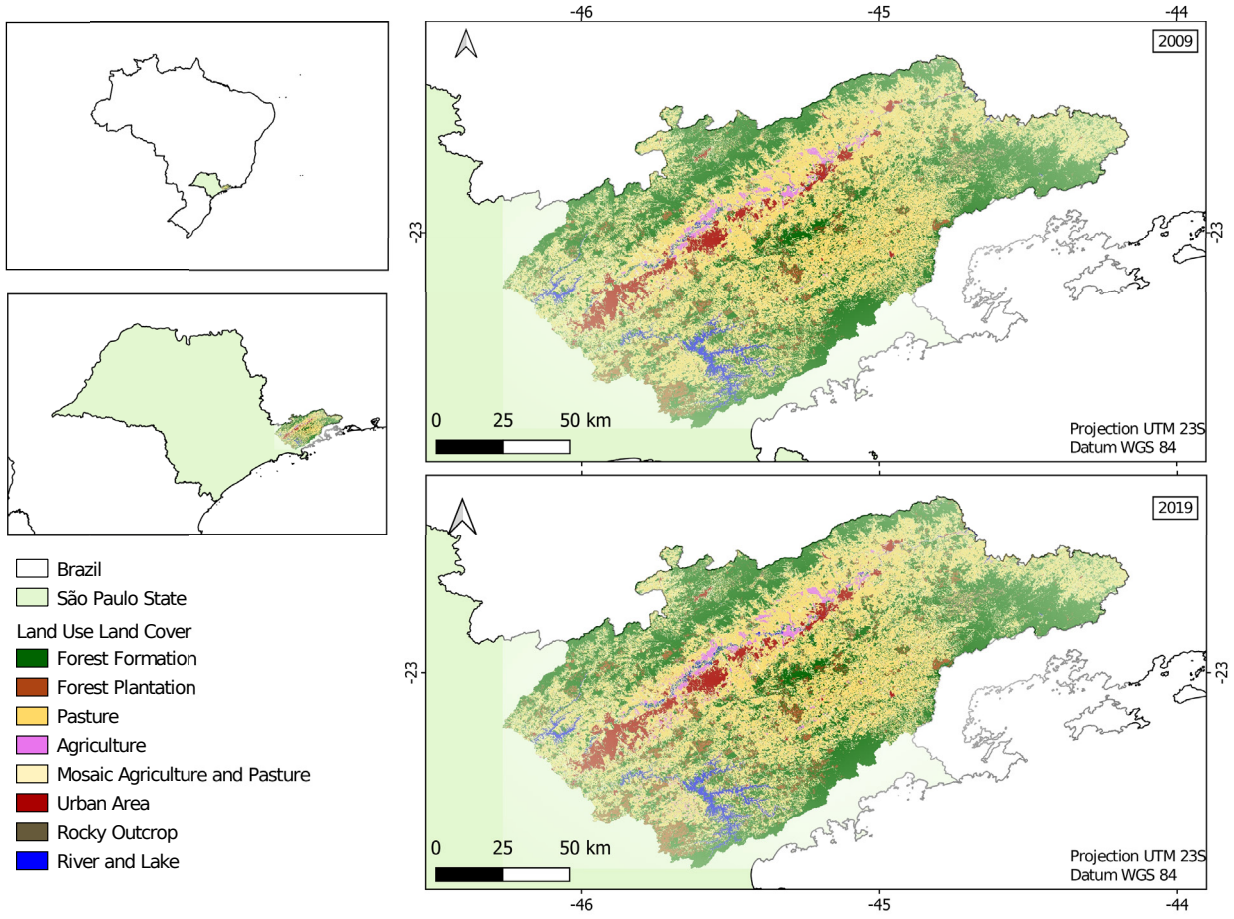

Figure 2. Land use and change from 2009 to 2020 in Vale do Paraíba Paulista, São Paulo state, southeast Brazil (data source from MapBiomas Project 2021).

about 14,000 square kilometers (IBGE 2021), and the Paraíba do Sul river supplies water, energy, dilution and irrigation to more than 15,700,000 people in the states of São Paulo, Rio de Janeiro and Minas Gerais (AGEVAP 2020). CEIVAP (Committee for Integration of the Paraíba do Sul River Basin) is responsible for articulating initiatives and projects in the basin between Minas Gerais, Rio de Janeiro and São Paulo states (AGEVAP 2020). In São Paulo state, CBH - Hydrographic Basin Committee - Paraíba do Sul (São Paulo section) is responsible for Water Resources Management Unit 02 (UGRHI-02). In addition several other private and public stakeholders contribute to the landscape management.

Historically, coffee and sugar cane production in the 19th century cleared much of the Atlantic Forest in Paraíba do Sul river basin (most of remaining native forest is located on both mountain chains Serra do Mar and Serra da Mantiqueira) and then transitioned to pasture for dairy and livestock production in the 20th century as markets for coffee and sugar cane changed (Devide et al. 2014). Lately, it has become a focus for regeneration of the Atlantic Forest biome (Silva et al. 2016), and from 2009 to 2020, vegetation cover has increased in the region (Figure 2). The region has 38 protected areas, of which 12 are of Full Protection and 26 are of Sustainable Use, covering an area of 4,458.54 square kilometers, that is, 31% of basin area (CBH-PS 2021). Besides that, natural disasters have been increasing in the region, following the national pattern (Figure 1).

The economy of the Metropolitan region of "Vale do Paraíba e Litoral Norte" is based on industry and is responsible for 4.7 % of national GDP (IBGE 2021). Despite that, it is a very unequal region, with wealth, developed and big cities and poor, undeveloped and small cities (IBGE 2017). Although the landscape is mostly natural and semi-natural (Figure 2), urban population predominates (IPVS SEADE 2021).

Data collection

Regarding PES projects, call notices ("editais") of federal, state and municipal PES projects were searched and used, in addition to private sector or non-governmental organization (NGO) programs. The calls define PES program objectives, actions contemplated, eligibility requirements, target audience, beneficiaries, papers and documents needed for joining the program and such. In Supplementary Material – Appendix S1, we present an example of a call notice of the Conexão Mata Atlântica (Atlantic Forest Connection) PES program, one of the programs studied, in one of its versions throughout its releases.

In 2009, a São Paulo state law (Lei 13798/2009: São Paulo 2009) instituted for the first time payment for ecosystem services as a public policy, and due to that, our start date for searched projects was 2009 until 2020. Search was made at official websites of each municipality, in addition to direct contact by e-mail or telephone to Departments of Environment or Agriculture, or similar, when necessary. We also searched for bills or municipal laws on Payment for Environmental Services available at Municipal Councils. State and federal projects were also searched at official websites of São Paulo state and State Secretary of Environment and Infrastructure (SIMA) and of national government agencies such as Paraíba do Sul River Basin Integration Committee (CEIVAP). NGO and private sector PES programs were also searched at official websites (for example The Nature Conservancy, World Resources Institute, etc). All found call notices were organized in tables and were analyzed, both quantitatively and qualitatively. Quantitatively, they were summed (public and private projects) per municipality and year and analyzed statistically. Qualitatively, call notices were read and we looked for words, concepts, actions, practices in these notices that would relate the PES project to the prevention of natural disasters, regarding soil conservation, climate change, ecosystem restoration, water preservation, ecosystem services, among others. Specifically, we looked for mentions to the words: "disasters", "risk", "danger", "preservation", "conservation", "prevention", "mitigation", "protection", "maintenance", "monitoring", "soil conservation practices", "restoration", "reforestation ", "recovery", "regeneration", "repair", "resilience", "vegetation", "plant cover", "Atlantic Forest", "sustainability", "sustainable development", "environmental services", "ecosystem services" , "regulation", "provision", "support", "cultural", "priority areas", "Conservation Units (UC)" and "reserves".

In addition, natural disaster occurrences (specifically flood and landslides) in the region, at the Brazilian Atlas of Disasters, São Paulo (UFSC-CEPED 2013), from 2009 to 2012, and at S2ID platform, from 2012 to 2020 were searched. We also identified natural disaster events at search websites and regional news websites. Fire data, related to ecological damage, was obtained from Queimadas Program platform at the Instituto Nacional de Pesquisas Espaciais (INPE) (http://queimadas.dgi.inpe.br/queimadas/portal). Drought data were obtained from the Centro Nacional de Monitoramento e Alertas de Desastres Naturais (CEMADEN), as an Integrated Drought Index (IDI). Lastly, natural disaster occurrences were summed to the number of disasters per municipality and year.

Statistical analysis

To analyze if municipalities with more disaster events preceded more PES projects, we performed Pearson's correlation test, to verify if a change to one variable leads to an observable change in another variable, with no cause and effect relation between them. Tests were performed using total calls and total natural disasters per municipality in the studied period when relating the two variables. Analyzes were performed in R version 3.6.3 (R Core Team 2019).

RESULTS AND DISCUSSION

Nineteen programs of Payments for Environmental Services, public or private, in all municipalities of Vale do Paraíba Paulista were found (Table I: different calls of the same program were counted individually). PES programs in the region were very diverse, mainly with the goal to forest conservation as reforestation actions. Some were focused on specific municipalities, such as Guaratinguetá (Water Producer Project: Produtor de Água) and São José dos Campos (Stream Ribeirão das Couves), and some on several municipalities or even protected areas, such as the Private Natural Heritage Reserves (RPPN: Reserva Particular do Patrimônio Natural) (Table I). The Atlantic Forest Connection (CMA: Conexão Mata Atlântica) project stood out, with eleven public notices covering municipalities in the Vale do Paraíba Paulista and the most recent PES projects in the region, from 2018 and 2019. The first PES project found was from 2011, two years after the state legislation that instituted PES in São Paulo state, and the most recent was from 2019 (probably due to the global pandemic of Covid-19 that restricted in person activities in 2020). We also verified that projects varied in the total amount paid (from about 35,000 to 2,000,000 dollars) and total area (from about 100 to 3,000 ha: Table I). Actions were mainly related to forest conservation, ecosystem restoration and a few PES also promoted soil conservation practices (Table I).

Regarding municipalities, more than half (19 municipalities) joined some PES program (Table II). In addition, municipalities that joined PES programs one time, did for other times, indicating how beneficial it could be for the municipality to participate in PES programs; i.e. in addition to protecting and conserving ecosystems, it is a source of extra income for rural producers (Schettini et al. 2020). We also verified that 11 municipalities that joined PES programas had forest gains (although small), while the majority of municipalities that did not join PES programs had forest loss (Table II). This slight increase in forest cover in the region (seen in Table II and Figure 2), as observed in data source of the MapBiomas Project (2021), was already pointed out in the region (Sapucci et al. 2021, 2022). We cannot attribute the forest gain only to the PES programs in each municipality, but landscape quality improvement related to PES projects may consequently be leading to forest gains, as indicated by Fiorini et al. (2020) for Brazilian Atlantic forest of PES participating properties and landscapes. Eight municipalities that agreed to PES programs had a high proportion of rural population (at least 10%) and twelve had small urban areas (less than 5 square kilometers), evidencing the targeting of rural communities in these programs. Lastly, most municipalities in the region did not have any PES local regulation (only five that agreed to PES programs had municipal regulations regarding PES: Table II). Municipalities that do not have PES regulations could join to state or federal programs, although local regulation decreases the chance and impacts of political and administrative discontinuities, ensuring permanence of long-term programs (Coelho et al. 2021).

Table I. PES call notices between 2009 and 2020, relating start and end date, municipalities covered, total project area, amount paid, main planned actions and links for access in Vale do Paraíba Paulista, Brazil.

Call notices	Year	Start date	End date	Coverage	Properties joined	Total project area [ha]	Amount paid [US$]	Main planned actions	Access link
001 Produtor de Água	2011	September 13, 2011	-	Guaratinguetá	24	-	-	Soil conservation; Forest restoration; Existing forests conservation.	http://sigaceivap.org.br:8080/publicacoesArquivos/arq_pubMidia_Processo_133-2015_VolumeI-P3.pdf
001 CAP RPPN*	2013	October 14, 2013	October, 2018	Cruzeiro, Guaratinguetá, Queluz, Santa Isabel	11	1,884.34	336,765.95	Conservation of remaining vegetation; Planting of native seedlings; Management of forest remnants; Monitoring.	https://smastr16.blob.core.windows.net/fundacaoflorestal/2014/12/Edital-n-01-2013-CAP-RPPN.pdf
001 Produtor de Água	2015	August 17, 2015	-	Guaratinguetá	17	-	-	Soil conservation; Forest restoration; Existing forests conservation.	http://sigaceivap.org.br:8080/publicacoesArquivos/arq_pubMidia_Processo_133-2015_VolumeI-P3.pdf
001 PES Ribeirão das Couves	2015	April 24, 2015	April, 2017	São José dos Campos	-	-	282,325.78	Protection of remnants of native vegetation; Restoration of degraded APP; Monitoring.	https://servicos2.sjc.sp.gov.br/media/519963/edital_psa_couves.pdf
002 CAP RPPN	2015	November 04, 2015	November, 2020	Guaratinguetá, Lavrinhas, Queluz, Santa Isabel, São José do Barreiro	8	770.00	139,868.09	Conservation of remaining vegetation; Planting of native seedlings; Management of forest remnants; Monitoring.	https://smastr16.blob.core.windows.net/fundacaoflorestal/2014/12/2-Edital_CAP-RPPN.pdf
001 PDSR**	2017	December 01, 2017	-	Bananal, Natividade da Serra, Paraibuna, São José dos Campos, São Luiz do Paraitinga	-	-	265,783.09	Fence implantation; Installation of firebreaks; Green adubation.	https://smastr16.blob.core.windows.net/editais/2017/12/edital_psa_mataciliar_sma.pdf
001 CMA***	2018	March 26, 2018	March, 2022	Paraibuna	5	104.4	35,437.74	Conservation of remnants of native vegetation.	https://smastr16.blob.core.windows.net/conexaomataatlantica/2019/03/edital_psa_001_2018.pdf
001 PDSR	2018	February 09, 2018	-	Cunha, São José dos Campos	-	-	124,032.11	Fence implantation; Installation of firebreaks.	https://smastr16.blob.core.windows.net/editais/2018/02/edital_psa_mataciliar_sma_01_2018_republicado.pdf
001 Produtor de Água	2018	March 27, 2018	-	Guaratinguetá	-	-	-	Soil conservation; Forest restoration; Existing forests conservation.	https://guaratingueta.sp.gov.br/wp-content/uploads/2018/03/DI%C3%81RIO-EXTRA-14-MAR%C3%87O.pdf

Table I. Continuation.

003 CMA	2018	July 09, 2018	July, 2022	São Luiz do Paraitinga, Natividade da Serra, São José dos Campos, Bananal	17	-	2,338,891.15	Conservation of private forests; Ecological restoration of private native forests; Productive conversion of pastures and degraded lands.	https://smastr16.blob.core.windows.net/conexaomataatlantica/2019/03/edital_psa_003_2018.pdf
004 CMA	2018	September 10, 2018	September, 2022	Paraibuna, Redenção da Serra	56	1,382.34	88,594.36	Protection and management of forest fragments; Expand carbon stock; Habitat conservation; Strengthen participating public and private bodies.	https://smastr16.blob.core.windows.net/conexaomataatlantica/2019/03/edital_psa_004_2018.pdf
005 CMA	2018	September 03, 2018	September, 2022	Cunha, Lagoinha	49	909.35	177,188.72	Protection and management of forest fragments; Expand carbon stock; Habitat conservation; Strengthen participating public and private bodies.	https://smastr16.blob.core.windows.net/conexaomataatlantica/2019/03/edital_psa_005_2018.pdf
006 CMA	2018	October 15, 2018	October, 2022	São Luiz do Paraitinga, Natividade da Serra, São José dos Campos, Bananal	23	-	2,338,891.15	Conservation of private forests; Ecological restoration of private native forests; Productive conversion of pastures and degraded lands.	https://smastr16.blob.core.windows.net/conexaomataatlantica/2019/03/edital_psa_006_2018.pdf
007 CMA	2018	December 12,2018	December, 2022	Areias, Silveiras	67	2,997.52	389,815.19	Protection and management of forest fragments; Expand carbon stock; Habitat conservation; Strengthen participating public and private bodies.	https://smastr16.blob.core.windows.net/conexaomataatlantica/2019/03/edital-de-selecao-publica-psa-007_2018.pdf
001 CMA	2019	January 05, 2019	January, 2023	São Luiz do Paraitinga, Natividade da Serra, Paraibuna, Redenção da Serra, Lagoinha, Cunha, Areias, Silveiras, Lorena, Guaratinguetá, Taubaté, Cachoeira Paulista	-	-	177,188.72	Support the isolation and protection of areas under restoration with fencing.	https://smastr16.blob.core.windows.net/conexaomataatlantica/2019/02/edital_psa_001_2019.pdf

Table I. Continuation.

002 CMA	2019	April 08, 2019	April, 2023	Paraibuna, Redenção da Serra, Lagoinha, Cunha, Areias, Silveiras, Cachoeira Paulista, Guaratinguetá, Lorena, Taubaté	89	2,202.44	531,566.17	Protection and management of forest fragments; Expand carbon stock; Habitat conservation; Strengthen participating public and private bodies.	https://smastr16.blob.core.windows.net/conexaomataatlantica/2019/02/edital_psa_002_2019.pdf
003 CMA	2019	May 30, 2019	May, 2023	Paraibuna, Redenção da Serra, Lagoinha, Cunha, Areias, Silveiras, Cachoeira Paulista, Guaratinguetá, Lorena, Taubaté	101	1,817.56	531,566.17	Protection and management of forest fragments; Expand carbon stock; Habitat conservation; Strengthen participating public and private bodies.	https://smastr16.blob.core.windows.net/conexaomataatlantica/2019/04/edital-psa-protecao-003_2019.pdf
004 CMA	2019	July 29, 2019	July, 2023	Paraibuna, Redenção da Serra, Lagoinha, Cunha, Areias, Silveiras, Cachoeira Paulista, Guaratinguetá, Lorena, Taubaté	33	619.62	177,188.72	Protection and management of forest fragments; Expand carbon stock; Habitat conservation; Strengthen participating public and private bodies.	https://smastr16.blob.core.windows.net/conexaomataatlantica/2019/06/edital_psa-004_2019_protecao.pdf
005 CMA	2019	June 27, 2019	June, 2023	São José dos Campos	7	601.45	124,032.11	Conservation of private forests; Ecological restoration of private native forests; Productive conversion of pastures and degraded lands.	https://smastr16.blob.core.windows.net/conexaomataatlantica/2019/06/psa-uso-multiplo-edital-psa-005_2019.pdf

***CAP RPPN: São Paulo Environmental Credit for Private Natural Heritage Reserves. ** PDSR: Sustainable Rural Development Project; *** CMA: Atlantic Forest Connection; 1US$ = R$5.64.**

Statistical correlation between payments for environmental services and natural D disasters in the Vale do Paraíba Paulista

We found a positive relation between total events of natural disaster preceding PES calls in Vale do Paraíba Paulista (P-value=0.036, coef=0.360: Figure 3). Specifically, fire occurrences (P-value=0.049, coef=0.341) and droughts (P-value=0.039, coef=0.344) were positively correlated to PES programs in the region. Landslides and floods were not associated with PES projects (P-value=0.159, coef=0.247; P-value=0.080, coef=0.304; respectively). It is interesting to consider that different types of disasters may be differently related to PES implementation and also that the effect of PES outcomes on, for instance, drought and fires may be distinct in terms of spatial and temporal scales when compared to flood and landslides in the region. Thus, PES programs (and forest restoration and conservation actions) are likely being implemented in response to the increase in natural disasters, besides other motives, as forests provide regulating services (Griscom et al. 2017). However, we surely understand that

Table II. Information regarding urban and rural areas, population, forest loss and gain (data source from MapBiomas Project 2021), number of PES calls and existing municipal regulation about PES for 34 municipalities of the Vale do Paraíba Paulista, Brazil.

Municipality	Area [km²]	Urban Area (2020) [km²]	Agricultural and Livestock Area (2020) [km²]	Estimated population (2021)	Rural population [%]	Forest loss between 2009 and 2020 [%]	Forest gain between 2009 and 2020 [%]	No. of PES Notices	Municipal regulation of PES
Aparecida	120.890	8.56	78.93	36,211	0.65	2.77	-	0	Yes
Arapeí	156.903	0.33	92.26	35,007	0.52	3.70	-	0	No
Areias	305.227	0.65	161.50	3,696	10.39	1.00	-	5	No
Bananal	616.429	1.28	288.62	10,223	6.63	-	0.55	3	No
Caçapava	368.990	37.75	264.72	84,752	0.71	3.21	-	0	No
Cachoeira Paulista	287.990	6.99	238.68	30,091	2.77	0.80	-	4	Yes
Canas	53.261	2.80	45.20	4,385	3.10	21.21	-	0	No
Cruzeiro	305.699	15.18	179.80	77,039	0.61	-	2.62	2	Yes
Cunha	1,407.250	4.47	915.41	21,866	24.78	-	3.43	6	No
Guararema	270.819	16.43	157.42	25,844	3.84	-	3.19	0	No
Guaratinguetá	752.636	32.51	476.51	112,072	1.33	-	1.82	9	Yes
Igaratá	292.953	2.21	153.06	8,831	4.11	-	1.22	0	No
Jacareí	464.272	63.07	291.77	221,214	1.38	2.94	-	0	No
Jambeiro	184.413	2.01	131.99	5,349	9.29	5.77	-	0	No
Lagoinha	255.472	0.59	189.87	4,841	16.42	-	3.62	5	No
Lavrinhas	167.067	2.55	92.41	6,590	3.00	-	1.17	1	No
Lorena	414.160	18.27	300.78	82,537	0.83	-	6.95	4	Yes
Monteiro Lobato	332.742	0.32	139.23	4,120	8.69	-	2.24	0	No
Natividade da Serra	833.372	0.99	366.67	6,678	26.00	-	1.53	4	No
Paraibuna	809.576	3.69	445.10	17,388	8.29	2.77	-	7	No
Pindamonhangaba	731.355	47.32	443.55	146,995	0.97	-	0.39	0	No
Piquete	175.996	2.43	84.93	14,107	1.84	-	1.51	0	No
Potim	44.643	2.65	39.89	19,397	0.78	2.36	-	0	No
Queluz	249.399	3.08	121.68	11,309	1.75	2.51	-	2	No
Redenção da Serra	309.441	0.72	189.53	3,873	22.67	-	4.16	5	No
Roseira	129.847	4.25	82.45	9,599	2.29	-	1.39	0	No
Santa Branca	272.238	2.64	190.28	13,763	2.89	5.12	-	0	No
Santa Isabel	363.332	12.53	197.50	50,453	1.85	0.07	-	2	No
São José do Barreiro	570.685	0.64	197.36	4,077	16.73	1.51	-	1	No
São José dos Campos	1,099.409	157.25	568.10	629,921	0.27	-	3.03	6	Yes
São Luiz do Paraitinga	617.315	1.58	363.79	10,397	13.93	0.86	-	5	No
Silveiras	414.782	0.83	250.38	5,792	16.53	-	3.39	5	No
Taubaté	625.003	79.25	398.10	278,686	0.50	0.98	-	4	No
Tremembé	191.094	11.65	124.67	40,984	1.58	-	3.91	0	No

Data obtained from: IBGE 2017, IBGE 2021, MapBiomas Project 2021.

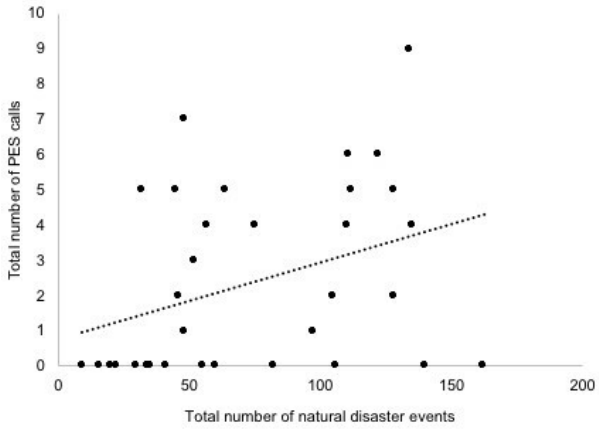

Figure 3. Relationship between total number of natural disaster events and PES calls in Vale do Paraíba Paulista, Brazil.

the main objectives of PES programs in Vale do Paraíba are not natural disasters, but other ecosystem services, such as water production. As ecological processes and ecosystem services are all integrated (Raum 2018), one aim (water regulation) in PES projects pulls others (such as natural hazard regulation). We have to stress that this pattern, more disasters more PES, might not necessarily indicate a causal relation and other variables not observed in the study could correlate to both disaster events and PES implementation.

Although our results were significant, study sample size was small, attributed to the small number of programs in the basin (only 19), the small area of rural properties taking part in projects, and to recent history of PES programs in the region (most PES programs started in 2018 and 2019). Additionally, many factors may interact for more programs in response to natural disasters, such as programs efficiency, acceptability of local communities, financing, management of the ONG and local government.

Mentions to natural disaster prevention in PES call notices

The search for words, concepts, actions, practices in the call notices relating PES projects to the prevention of natural disasters showed that the focus of implemented actions was on vegetation, conservation, restoration and protection (Table I and Figure 4), which is aligned to Sendai Framework objectives (UNDRR 2015) to reduce disaster risks, although disasters themselves were not addressed in the notices. Other important actions referred in these calls were maintenance, recovery, regeneration, monitoring, preservation (Figure 4).

The studied Payment for Environmental Services Programs were targeted to the conservation and restoration of the Atlantic Forest biome, located in the Vale do Paraíba Paulista region (Devide et al. 2014). Specifically, Conservation Units (UC: protected areas; Brasil 2000) and their buffer zones were priority regions and most targeted by programs, especially private protected areas, such as Private Natural Heritage Reserves (RPPN: Reserva Particular do Patrimônio Natural).

In general, the PES call notices did not directly address natural disasters or actions to prevent natural disasters. We found actions related to soil conservation practices and vegetation cover that might prevent landslides, floods, droughts and fires, but there were no mentions of these disasters and no special attention to regulating ecosystem services in those call notices. Although environmental hazards are not a focus, risks and dangers were addressed, including risks of erosion and fire.

It is very clear that vegetation conservation and restoration were the focuses of PES projects implemented in the Basin. Actions were related to the increase in vegetation cover along streams, river, springs and water recharge sites, all of them Permanent Preservation Areas (APP: Área de Preservação Permanente), protected areas inside private rural land where direct economic use is not allowed according to New Forest Code (Brasil 2012) and the law mandates

Figure 4. Tag cloud for the search of mentions to natural disaster prevention in PES projects in Vale do Paraíba Paulista, Brazil.

forest cover, making that PES just to follow this code. Restoration of APPs were the center of PES actions, because they affect water quantity and security (Tambosi et al. 2015), in an economically essential river basin among two major Brazilian metropolitan regions (Paraíba do Sul). However, it is concerning that PES in Vale do Paraíba Paulista programs have not been addressing natural disaster risk reduction in a patchy landscape of tropical forest remnants and pastures (Sapucci et al. 2021), where recurrent floods, droughts, anthropogenic fires and erosion problems associated with hilly reliefs (INPE 2021, AGEVAP 2020) make the region of great relevance.

Along with restoration, conservation of biodiversity and natural resources, carbon stocks, water production and biodiversity are major objectives of carrying out Payment for Environmental Services programs (Benayas et al. 2009). Climate regulation, nutrient cycling, and cultural services are, in general, second place objectives (Carlucci et al. 2020). That may be attributed to the fact that ecosystem services (ecological economics as a theoretical framework of PES) have been thought as an use value in the region, according to Costanza et al. (1997). Thus, the reality of PES projects in Paraíba Paulista valley are not different from other studies (Wilhelm et al. 2020, Waylen & Martin-Ortega 2020). Even in ecosystems subjected to more damaging natural hazards, such as mountainous and coastal areas, the relation between environmental disasters and ecosystem services needs to be better addressed (Unterberger & Olschewski 2021, Baustian et al. 2020).

Implemented practices such as green manure planting, direct planting, agroforestry, fencing and fire breaks were verified in PES projects that could help in the provision of a variety of ecosystem services, especially regulating services, but the importance and provision of these services were not made explicit in PES calls. In addition, forest recovery in abandoned land, another action verified in the studied PES projects, connects vegetation through corridors in the Vale do Paraíba fragments (Silva et al. 2016, Rocha et al. 2020) and may prevent degradation processes and natural hazards, which again was not mentioned as a preventive action against disasters. We believe that a table presenting predicted actions in the PES projects and each ecosystem service related to each action would be of great importance to education of target audience and decision makers and management and monitoring of public policies. Also, a risk assessment and mapping of erosion and landslides, and other natural disasters, could prioritize areas subjected to PES programs.

CONCLUSIONS

This study aimed at verifying the inclusion of regulating services (namely prevention of natural disasters) in the call notices (editais) of PES programs developed from 2009 to 2020 in Paraíba do Sul river basin, Brazil, and its relation with the number of natural disaster events (specifically flood, drought, landslides and fire). We found a positive relation between total events of natural disaster, fire occurrences and droughts and PES calls in Vale do Paraíba Paulista, in agreement to what we expected. Lastly, we expected prevention of natural disasters through specific actions in PES calls, which we did not observe. We found actions related to soil conservation practices and vegetation cover that might prevent landslides, floods, droughts and fires, but there were no mentions of these disasters and no special attention to regulating ecosystem services in those call notices.

It is concerning that PES in Vale do Paraíba Paulista programs have not been addressing natural disaster risk reduction in a landscape, where floods, droughts, anthropogenic fires and erosion problems associated with hilly reliefs have been increasing in the last years. The Paraíba do Sul River basin sits on the fringe between the major metropolitan areas of São Paulo and Rio de Janeiro (the biggest Brazilian cities) and supplies water, energy, sewage dilution and irrigation to more than 15,7 million people in the states of São Paulo, Rio de Janeiro and Minas Gerais, which is why water regulation has been prioritized in PES projects.

Despite the recent approval of the National PES Policy (Lei 14.119/2021: Brasil 2021) bringing opportunities and guidelines for the expansion and improvement of PES programs in Brazil, there are still gaps when it comes to the use of ecosystem services to reduce the risk of disasters. Therefore, scientific researches and data that share local learning are important for organizing and improving future or ongoing programs, including the development of municipal legal frameworks that meet local needs.

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SUPPLEMENTARY MATERIAL

Appendix S1

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TSA wrote the manuscript and provided data for Table I and Table II and data for Figure 1 and 4. PT wrote the manuscript and provided data for Figure 2 and Supplementary Material 1. KGM wrote the manuscript, proofread the writing in english and provided data for Figure 3. All the authors contribuided for analys tools and performed the paper.