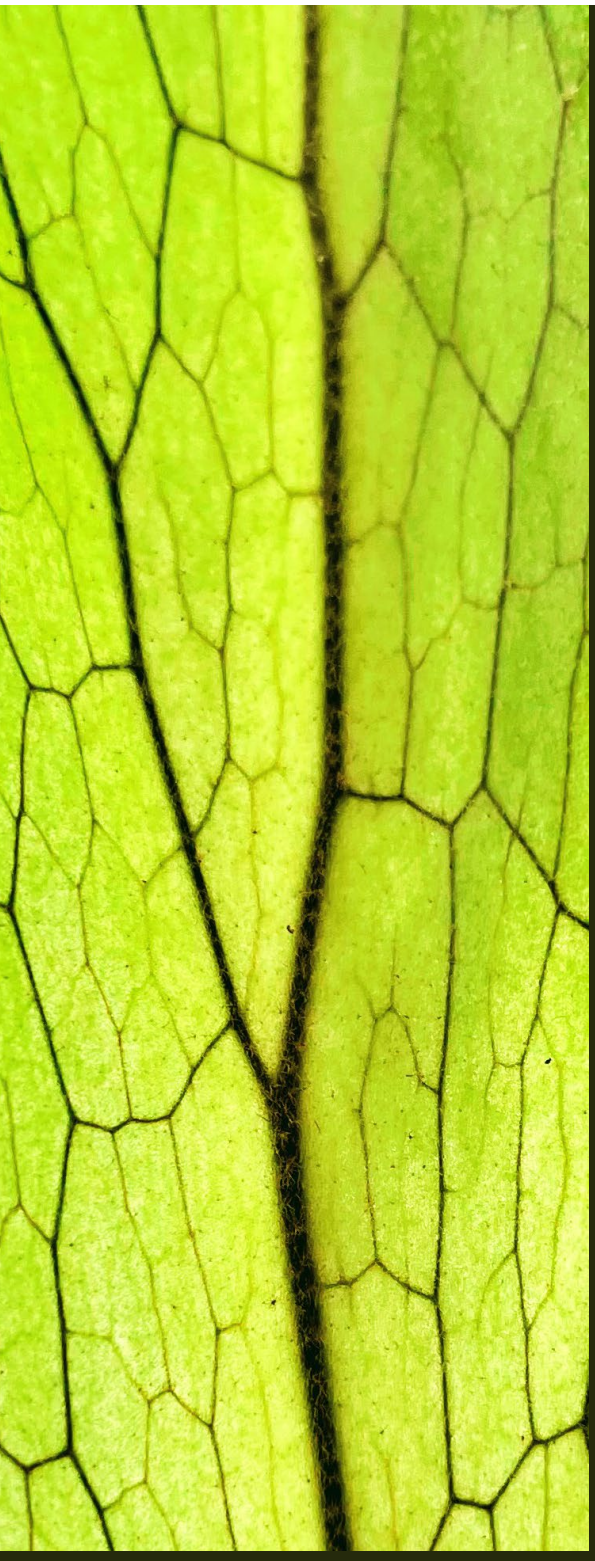
SUSTAINABILITY IN DEBATE

SUSTENTABILIDADE EM DEBATE



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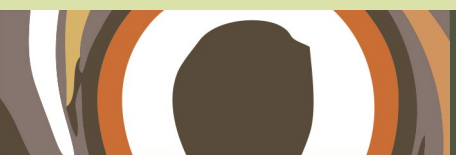

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Editorial

From the Montreal Protocol to the Climate Loss and Damage Agreement: lessons and warnings

Gabriela Litre, Marcel Bursztyn, Carlos Hiroo Saito and Patrícia Mesquita

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On September 23, 2019, in an interview with TIME magazine, the famous climate scientist Susan Solomon was asked why a society that managed to unite in the 1980s to handle the hole in the ozone layer in Antarctica still cannot do so to fight climate change (TIME, 2019). More than three years later, this question – and the inaction – are still accurate: why were we able to join forces to eliminate chlorofluorocarbons (CFCs) found in many refrigeration and personal care products, responsible for the depletion of the ozone layer and are now unable to combat the climate crisis?

Evidence of climate disaster abounds, and we do not need to mention the most recent report by the Intergovernmental Panel on Climate Change (IPCC), of which Solomon is a senior member. A simple recall is enough of that at the launch of the Working Group III report of the 6th assessment, on climate change mitigation, in April of this year, the Secretary-General of the United Nations, António Guterres, launched a particularly dismal message: "The jury has reached a verdict. And it is damning. This report of the Intergovernmental Panel on Climate Change is a litany of broken climate promises. It is a file of shame, cataloguing the empty pledges that put us firmly on track towards an unliveable world".

Nor do we need to remember here the countless daily testimonies of farmers from all origins, from the North and South Hemispheres, and under every economic situation possible, from large agribusiness to small producers, who feel the losses generated by climate change in their pockets. We do not even need to bring up the thousands of victims from floods, landslides, droughts, or even the rising costs of food, which mainly affect populations that are already historically vulnerable.

There is skin-deep evidence, the kind that even climate deniers cannot get away from, as it sticks like mosquitoes to day-to-day situations: 2022 was the hottest year ever measured in France since records began in 1900, announced Météo France on Wednesday, November 30, while stating that the phenomenon is an undeniable "symptom of climate change in France" (LE MONDE, 2022). It is an ideal environment for dengue. This scourge that seemed restricted to the tropical environment and that has also been felt for several years by residents and tourists in South Florida (USA) is now advancing on new frontiers without a visa or permission (STEPHENSON *et al.*, 2022). If climatological trends are confirmed, the prospects for the Zika virus terrify the United States and Europe (RYAN *et al.*, 2021).

Given these consequences of inaction in the face of the effects of current climate change, it is understandable that the experience of the ozone hole is considered an environmental success story: it was the only area where decisions were taken globally and on time, with a successful phasing out of the risk.

Nevertheless, if the news of the ozone hole was dramatic enough to stimulate the signing of the Montreal Protocol by the end of 1987, initiating the phasing out of CFCs, then why can't we repeat the feat? Why, despite the immense historical value of having reached an agreement on damages and losses signed this year in Egypt, do we leave yet another COP with a bitter taste in our mouths since the long-awaited agreement does not include essential information, naming the countries to be compensated nor how much money will they receive? (BBC, 2022).

The COP-27 declaration in Egypt did not specify which countries will benefit from the fund, nor the details of its financing mechanism, central points to be defined in "future" meetings. However, it is worth remembering that at the end of the Rio-92 conference (United Nations Conference on Environment and Development), there was a commitment for the wealthiest countries to allocate 0.7% of their GDP (gross domestic product) to development aid, an agreement whose effectiveness, predicted for until the year 2000, was never reached (BURSZTYN, M. A.; BURSZTYN, M., 2013). Several reasons could explain our climate inertia, and none of them leaves us in a comfortable situation as human beings, as they confirm our lack of altruism. We continue to be unable to think about humanity globally and with no vision of the future: we have crossed the limits of planetary resilience, but we are still very slow to react as if Mother Earth's resources and patience were infinite.

In the case of the depletion of the ozone layer, three reasons explain the speed of the resolution process: first, it quickly became clear that the risk generated was tangible and, above all, personal ("I" could get skin cancer and "my" children need to stay at home at certain times, due to solar radiation). It was not a matter of remote concern about the future of populations of small remote islands (postcard-like image) that are being swallowed by the sea.

Secondly, getting rid of CFCs in spray cans was an effortless thing to do. Without huge amounts of personal sacrifice, it was only necessary to stop using spray cans and start using pumps and cylinders for underarm deodorant. At the same time, converting CFCs to other alternatives for refrigeration equipment manufacturers opened up good market prospects with relatively little additional investment. It was, in other words, changing shelves at the supermarket, even without much impact on one's pocket. It is easier (and much cheaper) to change aerosol sprays than to get rid of the car and start cycling again. Even easier than reconverting the energy grid. Not even a war like the one in Ukraine managed to achieve this rapid conversion to renewables, and many countries opted for dubious shortcuts to guarantee energy in the Northern Hemisphere's winter.

However, the third reason that led to the ozone story's success can show us a way and encourage our actions in our days of climate struggle. According to Susan Solomon herself, there is a positive historical parallel between the fervour of activism in the 1970s and 1980s against aerosol cans in the United States and the strength of the international movement against climate change, with the youth movement led by Greta Thunberg, even if she has chosen not to participate in the COPs, tired of climate summits used to "greenwash, lie and deceive" (THE GUARDIAN, 2022).

Without further ado, what is certain is that the discovery of the ozone hole has sometimes been called a "focusing event" - an event that focuses public attention on a particular problem and which manages, for different reasons, to mobilise (TIME, 2019). Nowadays, the so-called "BIC countries" (Brazil, Indonesia and Congo), for example, have come together around another "focusing event": carbon emissions from deforestation/burning of their vast tropical forests.

The problem with "focusing events", similar to the "flagship species" adopted in biodiversity protection campaigns, is that they mobilise minds and hearts in a shallow way, without depth in the literacy process around the environmental processes involved, a mobilisation that fades too quickly and does not prepare for new similar challenges, as seen in the shift from CFCs to climate change.

It is still necessary to develop a broad and systemic view of the processes involved, considering the complexity of the interactions and the feedback and control processes. For example, taking the previously discussed energy matrix theme, we need to remember that the projected climate change scenarios indicate impacts on the generation of hydroelectricity, leading to greater activation of thermoelectric plants, which, in turn, positively feedback the mechanism that contributes to climate change: the increase in the emission of greenhouse gases (MICHELS-BRITO *et al.*, 2021). Therefore, getting the big picture is fundamental for future socio-environmental confrontations.

In the case of Brazil, which on January 1, 2023, begins to write a new stage in its history, a challenging process of rebuilding environmental policies and actions to fight deforestation will begin (FONSECA; LINDOSO; BURSZTYN, 2022). However, as with natural grasslands whose land has been razed, getting back "to normal" can be a slow and pharaonic task. A worrying finding is that, although difficult and slow, the resilience of instruments and policies resulting from an organised deconstruction process is greater than that of the ecosystems that are being devastated. Hopefully, no more lives will need to perish (human and non-human) until we collectively realise the urgency of acting responsibly towards Life on our Planet.

In its last issue of 2022, SiD publishes nine articles in the Varia section and the list of reviewers who collaborated with evaluating the works received throughout the year. We are immensely grateful for their dedication and time, turning our mission possible.

In the first group, focusing on the energy issue, Ramos Júnior *et al.* evaluate whether wind energy in Brazil has contributed to achieving the goals assumed in the Paris Agreement. Next, Soares & Barreto analysed the political arena around the issue of regulating the distributed generation of electricity in Brazil, elucidating the obstacles to its expansion, such as the disputes over narratives. Next, the article by González examines the relationships between the energy transition, society and the environment, focusing on the use of copper in Bolivia, Chile and Peru. In a second group, Ventura *et al.* evaluate the environmental benefits of implementing an urban mobility plan in Rio de Janeiro between 2011 and 2016. Onofre *et al.* analyse how the Pontal do Paraná Industrial Port Complex projects evaluated the cumulative impacts by analysing the Terms of Reference and Environmental Impact Studies of five projects. Through the use of a Social Urban Water Shortage Vulnerability Index, Ferrer *et al.* demonstrated unequal access to water between the different regions of a municipality in the state of São Paulo. Mendonça & Laques focus on a conceptual impact assessment model, especially aimed at agricultural research organisations, presenting a theoretical model applicable to research and innovation organisations in line with the United Nations' Sustainable Development Goals.

In the final group, Mendes *et al.* discuss the specific vulnerabilities, adaptive measures and opportunities identified in three groups with different socio-environmental profiles (traditional communities Fundo de Pasto in Northern Bahia, Tuxá indigenous community in Rodelas/BA and the irrigated perimeters of the Juazeiro/BA-Petrolina/PE pole). Finally, Dávalos and Rodrigues Filho also analyse the use of Social Network Analysis (SNA) in the Tuxás indigenous community in Bahia to understand the configuration of interaction and flow of information of the people and their multilevel relationship to face the environmental problem of drought.

We wish you all a good read and a healthy and peaceful New Year.

NOTES

1| Watch António Guterres' full message at https://bit.ly/ipcc-2022-3.

2| Participants at the United Nations Climate Summit in Egypt, COP27, reached a commitment for a new fund to compensate for "loss and damage" caused by natural disasters in "particularly vulnerable" developing countries. The deal, with many details yet to be decided on, supports the so-called "mosaic of solutions" called for by the EU negotiators, among other countries, which advocate new financial instruments to help pay for the damage caused by extreme events related to the climate crisis. This debate has been the central theme in climate summits since the 1990s. However, many points have not yet been defined.

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Editorial

Do Protocolo de Montreal ao Acordo sobre Perdas e Danos Climáticos: lições e advertências

Gabriela Litre, Marcel Bursztyn, Carlos Hiroo Saito e Patrícia Mesquita

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No dia 23 de setembro de 2019, a revista *Time* perguntou, em uma entrevista à renomada cientista climática, Susan Solomon, por que o mesmo mundo que nos anos 1980 conseguiu união para tratar do buraco da camada de ozônio na Antártica não conseguia, ainda, um entendimento para lutar contra as mudanças climáticas (TIME, 2019). Passados mais de três anos, a pergunta – e a inação – persiste: por que conseguimos juntar forças para eliminar os clorofluorcarbonetos (CFCs) encontrados em muitos produtos de refrigeração e higiene pessoal, responsáveis pela redução da camada de ozônio, mas ainda não para combater a crise climática?

Evidências do desastre climático não faltam, e não precisamos mencionar agora o mais recente relatório do Painel Intergovernamental sobre Mudanças Climáticas (IPCC), do qual Solomon é membro sênior. Basta lembrar que no lançamento do relatório do Grupo de Trabalho III de seu sexto ciclo de avaliação, sobre mitigação das mudanças climáticas, em abril deste ano, o secretário-geral das Nações Unidas, António Guterres, lançou uma mensagem especialmente lúgubre: “O júri chegou a um veredicto. E é condenatório. Este relatório do Painel Intergovernamental sobre Mudanças Climáticas é uma longa enumeração de promessas climáticas não cumpridas. É um arquivo da vergonha, catalogando as promessas vazias que nos colocam firmemente no caminho para um mundo inabitável”, disse Guterres.

Também não precisamos lembrar aqui dos inúmeros depoimentos cotidianos de agricultores de todas as origens, dos Hemisférios Norte e Sul, e de todos os perfis econômicos, desde o grande agronegócio ao pequeno produtor, que sentem no bolso as perdas geradas pelas mudanças climáticas. Nem precisamos trazer à tona as milhares de vítimas de enchentes, desabamentos, secas ou mesmo os crescentes custos dos alimentos, que afetam principalmente as populações que já são historicamente vulneráveis.

Existem evidências à flor da pele, dessas que nem os negacionistas climáticos conseguem afastar, pois elas se grudam como mosquitos no seu dia a dia: 2022 foi apontado como o ano mais quente já medido na França, desde que começaram os registros em 1900, anunciou o Météo France, em 30 de novembro, ao tempo que manifestou que o fenômeno é inegavelmente "um sintoma da mudança climática na França" (LE MONDE, 2022). Um ambiente ideal para a dengue, esse flagelo que parecia restrito ao ambiente tropical e que também já era sentido há vários anos por moradores e turistas no sul da Flórida (EUA), agora avança sobre novas fronteiras, sem visto nem permissão (STEPHENSON *et al*., 2022). As perspectivas para o Zika vírus, se as tendências climatológicas se confirmarem, aterrorizarão também os Estados Unidos e a Europa (RYAN *et al*., 2021).

Face a essas consequências da inação, ante os efeitos da mudança climática atual, é compreensível que a experiência do buraco da camada de ozônio seja considerada uma história de sucesso ambiental: foi realmente a única área em que as decisões foram tomadas, de uma maneira global e oportuna, e a eliminação progressiva do risco foi bem-sucedida.

Mas se a notícia do buraco na camada de ozônio foi dramática o suficiente para estimular a assinatura do Protocolo de Montreal até o fim de 1987, dando início à eliminação progressiva dos CFCs, por que, então, não conseguimos repetir a façanha? Por que, apesar do imenso valor histórico de termos conseguido um acordo de perdas e danos assinado neste ano no Egito, saímos de mais uma COP com gosto amargo na boca, pois o tão esperado acordo não inclui informações fundamentais, como quais países serão compensados nem quanto dinheiro receberão? (BBC, 2022).

A declaração da COP27, no Egito, não especificou quais países serão beneficiados pelo fundo nem os detalhes do mecanismo de financiamento desse fundo, pontos centrais que serão definidos em reuniões "futuras". Nunca é demais lembrar que ao final da Conferência Rio-92 (*United Nations Conference on Environment and Development*) houve um compromisso para que os países mais ricos destinassem 0,7% de seu produto interno bruto (PIB) à ajuda ao desenvolvimento, acerto cuja efetividade, prevista para até o ano 2000, nunca foi atingida (BURSZTYN, M. A.; BURSZTYN, M., 2013). Nossa inércia climática poderia ser explicada por vários motivos, e nenhum deles nos deixa em situação confortável como seres humanos, pois confirmam nossa falta de altruísmo: continuamos sem conseguir pensar na humanidade globalmente, e sem visão de futuro, passamos dos limites de resiliência planetários, mas seguimos muito lentos para reagir, como se os recursos e a paciência da Mãe-Terra fossem infinitos.

No caso da redução da camada de ozônio, três motivos explicam a celeridade do processo de resolução: em primeiro lugar, foi percebido rapidamente que o risco gerado era muito concreto e sobretudo pessoal ("eu" posso sofrer câncer de pele e preciso segurar as "minhas" crianças em casa em certos horários, por conta da radiação solar). Não se tratava de preocupação remota, sobre futuro de populações de pequenas ilhas afastadas (de cartão-postal) que estão sendo engolidas pelo mar.

Segundo motivo: se livrar dos CFCs em latas de *spray* era uma coisa muito fácil de se fazer. Sem grandes doses de sacrifício pessoal, só foi necessário parar de usar latas de *spray* e começar a usar as bombas e os cilindros para desodorante das axilas. Em paralelo, há que se considerar que para os fabricantes de equipamentos de refrigeração a conversão do uso de CFC para outras alternativas abria boas perspectivas de mercado, com relativamente pouco investimento adicional. Foi, em outras palavras, mudar de prateleira no supermercado, inclusive sem grande impacto no bolso. Resulta evidente que é mais fácil (e muito mais barato) mudar de aerossol do que se desfazer do carro e voltar a andar de bicicleta. Ainda mais fácil do que reconverter a malha energética. Nem sequer uma guerra como a da Ucrânia conseguiu essa rápida reconversão aos renováveis, e muitos países optaram por atalhos duvidosos para garantir energia no inverno do Hemisfério Norte.

Mas o terceiro motivo que levou ao sucesso da história do ozônio pode, sim, servir como exemplo e ser encorajador em nossos dias de luta climática: segundo a própria Susan Solomon, existe um paralelo histórico positivo entre o fervor do ativismo dos anos 1970 e 1980 contra as latas de aerossóis nos Estados Unidos e a força do movimento internacional contra a mudança do clima, como o de jovens liderados por Greta Thunberg. Isso, apesar de que a própria Greta tem optado por não participar das COPs, cansada de que as cúpulas do clima sejam usadas para "fazer *greenwashing*, mentir e enganar" (THE GUARDIAN, 2022).

Palavras mais, palavras menos, o certo é que a descoberta do buraco na camada de ozônio foi às vezes chamada de "evento de concentração" – um evento que focaliza a atenção pública sobre um problema particular, e que consegue, por diferentes motivos, mobilizar (TIME, 2019). Em nossos dias, os chamados "BIC countries" (Brasil, Indonésia e Congo), têm, por exemplo, se unido em torno de outro "evento de concentração": as emissões de carbono por desmatamento e queimadas das suas enormes florestas tropicais.

O problema dos "eventos de concentração", à semelhança das "espécies-bandeira" adotadas em campanhas de proteção da biodiversidade, é que mobilizam mentes e corações de forma rasa, sem profundidade no processo de letramento em torno dos processos ambientais envolvidos, mobilização

que se esvai muito rapidamente e não prepara para novos desafios similares, como se vê na passagem dos CFCs para as mudanças climáticas.

Falta desenvolver a visão ampla e sistêmica dos processos envolvidos, considerando a complexidade das interações e os processos de retroalimentação e controle. Por exemplo, tomando o tema matriz energética anteriormente tratado, é preciso lembrar que os cenários de mudanças climáticas projetados indicam impactos sobre a geração de hidroeletricidade, levando a uma maior ativação de termelétricas que, por sua vez, retroalimentam positivamente o próprio mecanismo contribuidor das mudanças climáticas: o aumento da emissão de gases de efeito estufa (MICHELS-BRITO *et al*., 2021). Apreender a visão do todo é fundamental para os enfrentamentos socioambientais do porvir.

No caso concreto do Brasil, que em 1º. de janeiro de 2023 começa a escrever uma nova etapa de sua história, será iniciado um desafiador processo de reconstrução de políticas e ações ambientais de luta contra o desmatamento (FONSECA; LINDOSO; BURSZTYN, 2022). Mas, como acontece com os campos naturais cuja terra foi arrasada, voltar "ao normal" pode resultar em uma tarefa lenta e faraônica. Uma constatação preocupante é que, ainda que difícil e lenta, a resiliência dos instrumentos e políticas que foram objeto de um processo organizado de desconstrução, é maior do que a dos ecossistemas que estão sendo devastados. Esperemos que não seja necessário perdermos mais vidas (humanas e não humanas) para percebermos de maneira coletiva a urgência de agirmos de forma responsável em relação à vida no nosso Planeta.

Em seu último número de 2022, a SeD publica nove artigos na seção *Varia* e a lista de pareceristas que colaboraram com a avaliação dos trabalhos recebidos ao longo do ano. Agradecemos imensamente o tempo despendido e a dedicação das e dos pareceristas, que fazem possível o nosso trabalho.

Em um primeiro bloco, focado na questão energética, Ramos Júnior *et al*. avaliam se a energia eólica no Brasil vem contribuindo para o cumprimento de metas assumidas no Acordo de Paris. Na sequência, Soares e Barreto analisaram a arena política em torno do tema de regulamentação da geração distribuída de energia elétrica no Brasil, elucidando os entraves à sua expansão, entre eles as disputas de narrativas. E, ainda nesse tópico, vem o artigo de González examinando as relações entre a transição energética, a sociedade e o meio ambiente, focando o uso do cobre nos países da Bolívia, Chile e Peru. Em um segundo bloco, Ventura *et al.* avaliam os benefícios ambientais relacionados à implementação de um plano de mobilidade urbana no Rio de Janeiro, entre 2011 e 2016. Onofre *et al*. analisam como os projetos do Complexo Industrial Portuário Pontal do Paraná avaliaram os impactos cumulativos, por meio de uma análise dos Termos de Referência e Estudos de Impacto Ambiental de cinco empreendimentos. Ferrer *et al.* demonstraram, por meio do uso de um Índice Social de Vulnerabilidade à Escassez de Água Urbana, o acesso desigual à água entre as diferentes regiões de um município no estado de São Paulo. Já Mendonça e Laques focam um modelo conceitual de avaliação de impacto, especialmente direcionado a organizações de pesquisa agropecuária, apresentando um modelo teórico aplicável a organizações de pesquisa e inovação em sintonia com os Objetivos de Desenvolvimento Sustentável das Nações Unidas.

E, em um último bloco, Mendes *et al.* discorrem sobre as vulnerabilidades específicas, medidas adaptativas e oportunidades identificadas em três grupos com diferentes perfis socioambientais (comunidades tradicionais Fundo de Pasto no norte da Bahia, comunidade indígena Tuxá, em Rodelas/BA, e os perímetros irrigados do polo Juazeiro/BA-Petrolina/PE). E, por fim, Dávalos e Rodrigues Filho analisam o uso da Análise de Redes Sociais (ARS) também na comunidade indígena Tuxás, na Bahia, com o intuito de compreender a configuração de interação e fluxo de informação do povo e sua relação multinível para enfrentar a problemática ambiental da seca.

Desejamos a todos(as) uma boa leitura e um fim de ano de saúde e paz.

NOTAS

1| A mensagem de António Guterres pode ser assistida na íntegra em https://bit.ly/ipcc-2022-3.

2| Os participantes da cúpula das Nações Unidas sobre o clima no Egito, COP27, chegaram a um compromisso de financiar um novo fundo para compensar "perdas e danos" causados por desastres naturais em países em desenvolvimento "particularmente vulneráveis". O acordo, com muitos detalhes ainda a serem finalizados, apoia a chamada "solução em mosaico" solicitada pelo bloco negociador da UE, entre outros países, que defende novos instrumentos financeiros para ajudar a pagar os danos causados após eventos extremos relacionados com a crise climática. Esse debate tinha sido o grande tema de fundo nas cúpulas climáticas desde os anos de 1990. Muitos pontos não foram ainda definidos.

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How wind energy is contributing to the achievement of Brazilian commitments to the Paris Agreement

Como a energia eólica está contribuindo para o Brasil atingir os compromissos assumidos no Acordo de Paris

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ARTICLE – VARIA

ABSTRACT

The Paris Agreement was signed to reduce greenhouse gas emissions, and Brazil is committed to increasing renewable energy participation in the electrical matrix. This study aims to evaluate how wind energy fulfils the goals determined in the agreement. Through a systematic literature review, 10 relevant studies were identified and together with the analysis of data available in the National Energy Balance report from the Energy Research Company. Comparing the data obtained in the period with the established targets was possible. The success of policies for the sector in reaching the goals above was also evaluated. The results show that wind energy is the renewable source that most benefited from tax incentives and, thus, contributed to the expansion of the share of renewable energy in the Brazilian electrical matrix.

Keywords: Paris agreement. Electrical sector. Renewable energy. Wind energy. Electrical efficiency.

RESUMO

O Acordo de Paris foi assinado com o intuito de reduzir as emissões de gases de efeito estufa. O Brasil se comprometeu a aumentar a participação de energias renováveis na matriz elétrica. O objetivo

deste estudo é avaliar como a energia eólica está contribuindo para o cumprimento das metas assumidas no Acordo. Por meio de uma revisão sistemática da literatura, foram identificados dez estudos pertinentes e, juntamente com uma análise dos dados disponíveis no Relatório de Balanço Energético Nacional, da Empresa de Pesquisa Energética (EPE), foi possível comparar os dados obtidos no período com as metas estabelecidas e avaliar o sucesso das políticas para o setor no atingimento dos objetivos mencionados. Os resultados demostram que a energia eólica é a fonte renovável que mais se beneficiou dos incentivos fiscais e, assim, contribuiu para a expansão da participação da energia renovável na matriz elétrica brasileira.

Palavras-chave: Acordo de Paris. Setor elétrico. Energia renovável. Energia eólica. Eficiência elétrica.

1 INTRODUCTION

The objective of the Paris agreement is to strengthen the global response to the threat of climate change by ensuring that the global average temperature increase is less than 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to up to 1.5°C above pre-industrial levels (UNFCCC, 2016). To reach this objective, governments constructed their own commitments based on the so-called Intended Nationally Determined Contributions (INDC). Each nation presented its contribution to reducing greenhouse gas emissions by the INDCs, following what each government considered feasible based on the local social and economic scenarios (MMA, 2016). Brazil has committed to reducing greenhouse gas emissions by 37% below 2005 levels by 2025, with a subsequent commitment to reduce greenhouse gas emissions by 43% below 2005 levels by 2030 (BRASIL, 2016). After the 2001 energy crisis, Brazil has been developing public policies to increase renewable electric energy in the National Electric System. Examples include the Emergency Wind Energy Program (Proeólica – Brazilian acronym) and the Incentive Program for Alternative Sources of Electric Energy (Proinfa – Brazilian acronym).

Following the Paris Agreement, the United Nations adopted, in 2015, the Sustainable Development Goals (SDGs) as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity. Goal 7 sets the challenge of affordable and clean energy for all (UNDP, 2022). Access to transparency and quality of public data are critical elements for good information governance to support decision-making and policy formulation. The Brazilian Institute of Geography and Statistics (IBGE – Brazilian acronym) has been advancing in nationalizing the SDG indicators (LINDOSO *et al.*, 2021). Of the seven corresponding global indicators, Brazil has already adapted the estimation methodology for six of them, whereas for one of them data is unavailable at a national scale (IBGE, 2022). Wind energy, a type of clean energy, which is widely distributed, pollution-free, and free of greenhouse gas emissions during operation (ZHANG, 2020), can benefit the country, ensuring universal, reliable, modern, and affordable access to electricity services. To make this happen, eliminating incentives to expand the exploration and use of fossil fuels (oil, gas, and coal) is essential, as well as reallocating investment resources from these sectors to expand the generation and use of renewable sources (GRUPO DE TRABALHO DA SOCIEDADE CIVIL, 2022).

The Energy Research Company (EPE – Brazilian acronym) predicts that the total energy consumption in Brazil will grow 3.5% per year until 2031, an average annual increase of 19.7 TWh. Residential consumption grows as the number of residential consumers increases. The evolution of consumption in the industrial sector stands out regarding the use of the installed capacity, and consumption in the commercial sector should grow mainly due to the pandemic (EPE, 2022). Meeting the increasing demand for energy while decreasing greenhouse gas and air pollutant emissions requires decarbonizing the electricity sector and providing electrical energy to at least parts of the transportation and industrial sectors (MORRISON *et al.*, 2015; ROCKSTRÖM *et al.*, 2017). However, large industries worldwide continue to rely on fossil fuels as an energy source

(GOMAA *et al.*, 2019). Although decarbonizing energy systems requires substantial infrastructure investments, it also yields large decreases in climate and health costs (JACOBSON *et al.*, 2018).

The future development of renewable energy sources, such as wind power, is one of the key factors for reducing greenhouse gas emissions (RAIMUNDO *et al.*, 2018). According to Abeeólica (2021), Brazilian-installed wind capacity increased more than two and a half times from 2014 to 2020, going from 5,974 MW to 17,747 MW, representing a significant average growth rate of 20% per year. Despite the significant growth of wind generation and other renewable sources besides hydro for electricity generation in recent years in Brazil, there was the risk of a new blackout in 2021, when the country faced its greatest water shortage since 1930 (MME, 2021). The water scarcity situation highlighted how the different uses of water affect the management of reservoirs (EPE, 2022).

This study aims to assess how wind energy contributes to Brazil's achievement of the commitments for the energy sector in the Paris Agreement. The available data from the Energy Research Office (EPE) from 2014 to 2020 and the relevant literature were analyzed.

This paper is organized into four sections: besides this Introduction, Section 2 describes the Materials and Methods used, Section 3 discusses the Results and Discussion, and Section 4 presents the Conclusions.

2 MATERIALS AND METHODS

The study was conducted via a systematic review of the literature and the analysis of data available in the National Energy Balance Report of the EPE, the Annual Bulletin of Wind Generation of the Brazilian Wind Energy Association (Abeeólica), and the Global Wind Energy Report published by the Global Wind Energy Council (Gwec). The period selected for analysis was from 2014 (before the Paris Agreement was signed) to 2020.

The databases used for the systematic review searches were Science Direct and Google Scholar. The descriptors used were: "Paris Agreement," "Wind Energy," and "Brazil." The inclusion criteria for the search of publications were: the relevance of content to the theme addressed in this study (assessed by the authors) and papers written in English and Portuguese. All papers published outside the defined period and languages, as well as theses and dissertations, were excluded.

After conducting the search, it was possible to find 181 studies related to the theme. Of these, 50 relevant studies were pre-selected. After reading the titles and abstracts, 10 studies were selected as relevant to compose this systematic review.

The expansion of domestic use of non-fossil energy sources by increasing the share of renewable energy (other than hydropower) was also studied. The current goal is to increase participation in the electricity supply to at least 23% by 2030. Consequently, the percentage contribution of these sources to the Brazilian electricity matrix from 2014 to 2020 was assessed. These include wind, biomass, and solar energy.

As for achieving 10% efficiency gains in the electricity sector, the losses from the difference between internal electricity supply (supply) and final consumption (demand) per year were estimated. The efficiency gain was evaluated by reducing losses during the generation, transmission, and distribution of electric energy in the period. The target was to reduce losses by 10% of the value of losses in 2014.

3 RESULTS AND DISCUSSION

This section is organized into five subsections: Subsection 1 focuses on the Paris Agreement; Subsection 2 focuses on the world and Brazilian electricity matrix; Subsection 3 shows the participation of renewable and non-renewable energies in the Brazilian electricity matrix; Subsection 4 addresses Efficiency in the Electricity Sector; Subsection 5 assesses the results of public policies for the expansion of wind power in Brazil.

3.1 THE PARIS AGREEMENT

The Paris Agreement is a global treaty that aims to reduce greenhouse gas emissions in the context of sustainable development. The agreement was negotiated during the 21st Conference of the Parties of the United Nations (COP21) in Paris and approved by the 195 countries of the United Nations Framework Convention on Climate Change on December 12, 2015.

Over the last decade, the use of wind power as a renewable energy source in the electricity sector has been growing faster than other available sources in Brazil and worldwide. For Arantegui and Jänger-Waldau (2018), wind energy is one of the leading technological options for shifting towards a decarbonized energy supply.

In 2015, around 27.3 GW of new power generation capacity was connected in the European Union. Renewable energy sources accounted for 20.6 GW or 75.6% of all new generation capacity. Wind energy contributed 12.2 GW, or 44.6% of the newly installed capacity, as reported by Arantegui and Jänger-Waldau (2018).

After approval by the National Congress, Brazil ratified the Paris Agreement. On September 2nd, the instrument was delivered to the United Nations. Thus, Brazilian targets have become official commitments. Regarding nationally determined contribution (NDC), Brazil has committed to reducing greenhouse gas emissions by 37% below 2005 levels in 2025, with a subsequent commitment to reduce greenhouse gas emissions by 43% below 2005 levels in 2030. For that, the country has committed to increasing the share of sustainable bioenergy in its energy matrix to approximately 18% by 2030, restoring and reforesting 12 million hectares of forests, as well as achieving an estimated 45% share of renewable energy in the composition of the energy matrix in 2030 (MMA, 2016).

For the electricity sector, the targets were (BRASIL, 2016):

I. Expand domestic use of non-fossil energy sources by increasing the share of renewable sources (other than hydropower) in electricity supply to at least 23% by 2030, including expanding the shares of wind, biomass, and solar sources.

II. Achieve 10% efficiency gains in the electricity sector by 2030.

As the CEBDS (2017) described, the goals set by the NDC are interdependent, so the challenge is to achieve them harmoniously and cooperatively. The objective is to maintain a high proportion of renewable energy in a matrix, with greater inclusion of renewable sources other than hydro, in an uncertain context of energy consumption growth by 2030, and with the additional target of increasing energy efficiency by 10%.

3.2 WORLD AND BRAZILIAN ELECTRICITY MATRIX

Figure 1 shows the use of renewable and non-renewable sources for electricity generation in Brazil and the world in 2019 (IEA, 2021).

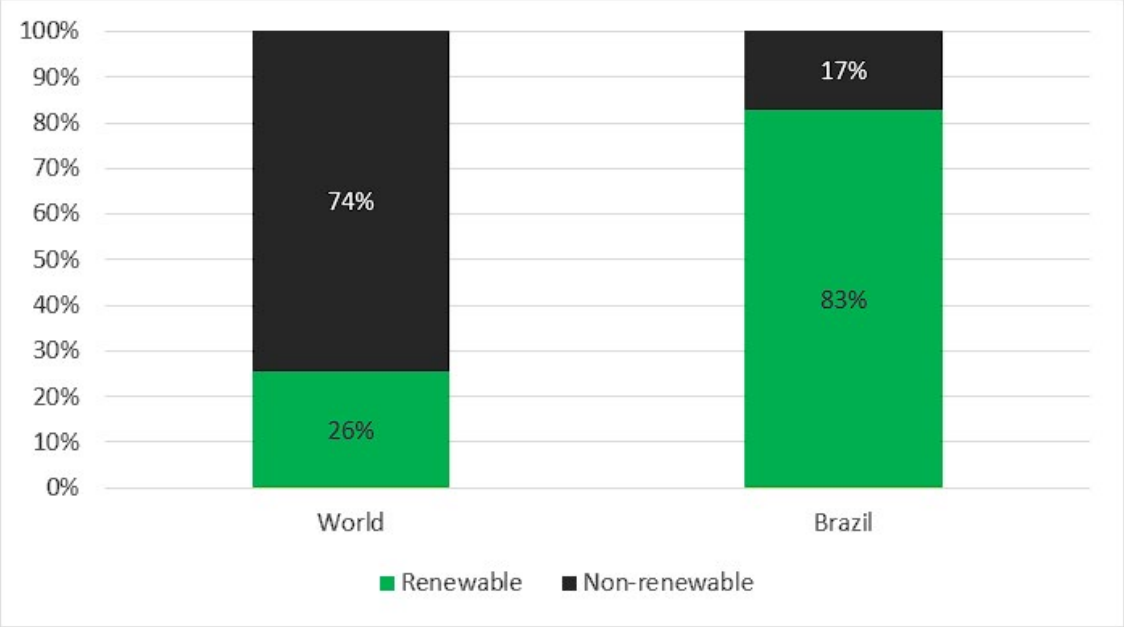

Figure 1 | Participation of renewable and non-renewable energy in the Brazilian and World Electricity Matrix in 2019

Source: IEA (2021).

The world's electricity matrix is composed mainly of non-renewable energy sources (74%), especially coal and natural gas, which account for 60% of the world's electricity matrix. On the other hand, the Brazilian electricity matrix is more renewable. Adding hydraulic, wind, biomass, solar, and other renewable sources, 83% of the Brazilian electric matrix is composed of renewable energy sources.

3.3 PARTICIPATION OF NON-RENEWABLE AND RENEWABLE ENERGY IN THE BRAZILIAN ELECTRICITY MATRIX

Table 1 shows data on domestic electricity supply by source from 2014 (before the Paris Agreement) to 2020.

Table 1 | Data of the Internal Electricity Supply

	2014 (GWh)	*2015 (GWh)*	*2016 (GWh)*	*2017 (GWh)*	*2018 (GWh)*	*2019 (GWh)*	*2020 (GWh)*
Natural Gas	81,073	79,490	56,485	65,593	54,622	60,448	53,464
Nuclear	15,378	14,734	15,864	15,739	15,674	16,129	14,053
Coal Vapor	18,385	18,856	17,001	16,257	14,204	15,327	11,946
Petroleum derivatives	30,834	25,014	11,808	12,458	9,293	6,926	7,746
Other non-renewable sources	12,127	11,826	11,919	12,256	12,314	12,061	11,121

	2014 (GWh)	2015 (GWh)	2016 (GWh)	2017 (GWh)	2018 (GWh)	2019 (GWh)	2020 (GWh)
NON-RENEWABLE (TOTAL)	**15,797**	**149,920**	**113,077**	**122,303**	**106,107**	**110,891**	**98,330**
Hydraulic + Net Imports	407,239	394,143	421,711	407,306	423,971	422,877	421,081
Biomass	47,079	49,880	51,335	52,913	54,383	54,920	58,742
Wind	12,210	21,626	33,489	42,373	48,475	55,986	57,051
Solar	16	59	85	832	3,461	6,655	10,748
RENEWABLE (TOTAL)	**466,544**	**465,708**	**506,620**	**503,424**	**530,290**	**540,438**	**547,622**
DOMESTIC ELECTRICITY SUPPLY	**624,341**	**615,628**	**619,697**	**625,727**	**636,397**	**651,329**	**645,952**

Source: EPE (2021).

Table 1 shows that in 2014 more non-renewable sources were used to generate electricity in Brazil than in 2020 and that renewable sources such as biomass, solar, and wind increased their participation in the Brazilian electricity matrix in all years of the period.

Figure 2 shows Brazil's domestic renewable electricity supply – excluding hydro – between 2014 and 2020.

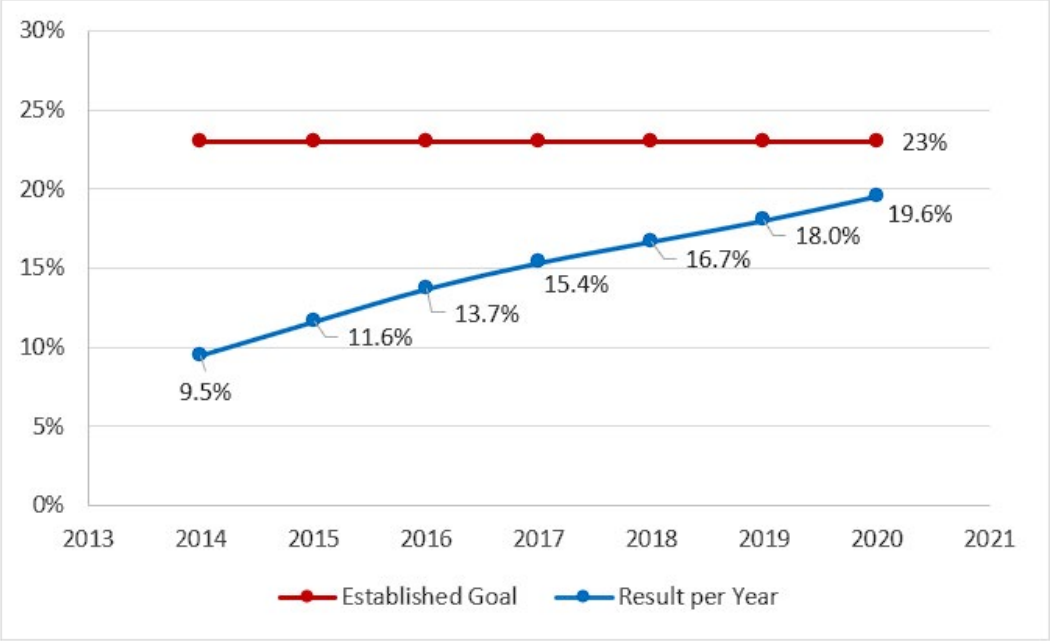

Figure 2 | Participation of Renewable Energy in the Brazilian Electricity Matrix (except hydroelectric power)

Source: EPE (2021).

As shown in Figure 2, excluding hydroelectric power, the share of renewable sources in the Brazilian electricity matrix grows in the period. In relation to expanding the domestic use of non-fossil energy sources by increasing the share of renewable energy (besides hydropower) in the electricity supply to at least 23% by 2030, the results show that Brazil is on the path to achieving the goal established in the Paris Agreement.

The period's main highlight was wind energy's contribution to the Brazilian electricity matrix. Although in 2014, the generation of electricity by wind power was 12,210 GWh, in 2020, the value was 57,051 GWh (an increase of 44,811 GWh). The share of biomass went from 44,987 GWh to 51,876 GWh (an increase of 6,899 GWh), and solar energy went from 16 GWh to 3,461 GWh (an increment of 3,445 GWh). Figure 3 shows the percentage contribution of biomass, wind, and solar sources to the national electricity matrix from 2014 to 2020.

Figure 3 shows the percentage contribution of biomass, wind, and solar sources to the national electricity matrix from 2014 to 2020.

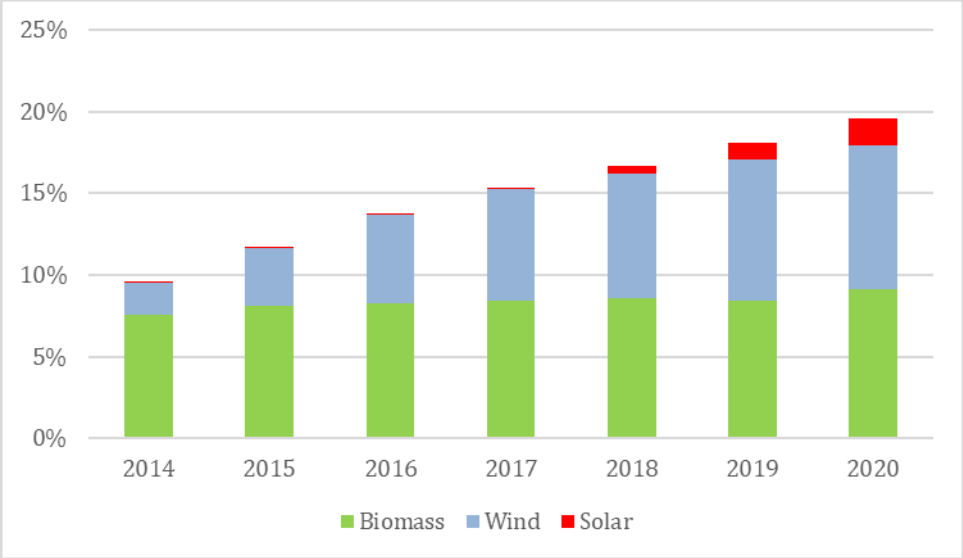

Figure 3 | Contribution of Biomass, Wind, and Solar Sources to the National Electric Matrix

Source: EPE (2021).

Figure 3 shows that wind energy was the source with the highest contribution in the period. In 2014, the 9.5% share of renewable energy for the Brazilian electric matrix (excluding hydroelectric source) was composed of 7.54% biomass, 1.95% wind, and 0.01% solar. In 2020, these shares were 9.09% biomass, 8.83% of wind, and 1.66% solar.

3.4 EFFICIENCY IN THE ELECTRICITY SECTOR

As Arantegui and Jänger-Waldau (2018) described, the European Council meeting defined the Climate and Energy Policies for 2030 to meet the goals of the Paris Agreement. A target was set to improve electrical efficiency by at least 27% in 2030. The goal established for Brazil in the Paris Agreement was to achieve 10% efficiency gains in the electricity sector by 2030.

The 2001 energy crisis ("The 2001 Blackout") was a national electricity crisis that affected the supply and distribution of electricity throughout the country. It occurred between July 1, 2001, and February 19, 2002, and was caused mainly by a lack of planning and investments in the Brazilian electricity sector. Hage (2019) indicates that, until the 2001 electricity crisis, Brazil had not made the necessary investments for the technical improvement of hydroelectric plants and power transmission companies, both State-owned. Altoé *et al.* (2017) emphasize that the hydric crisis, with the lack of long-term planning – considering the great dependence on hydraulic generation in the internal electricity supply – increased the need to activate a significant number of thermoelectric plants. Michels-Brito *et al.* (2021) warn that, besides the increase in CO2 emission, the use of thermoelectric energy to compensate for the hydropower deficit increases energy costs.

3.4.1 REGULATORY FRAMEWORKS FOR ENERGY EFFICIENCY INCENTIVES IN BRAZIL

Law 9,478, launched on August 6, 1997, established the principles and objectives of the National Energy Policy (PEN). This law established national policies for the rational use of energy sources to protect the environment, identify the most appropriate solutions for the supply of electricity in the country's many regions and attract investment in energy production (BRASIL, 1997).

On October 17, 2001, Law 10,295 was issued to establish the National Policy for Conservation and Rational Use of Energy, which aims to allocate energy resources and preserve the environment efficiently. This law established that the Executive Branch would be responsible for developing mechanisms to promote the energy efficiency of products, machinery, and equipment in the construction sector (BRASIL, 2001).

According to Altoé *et al.* (2017), in the following years, relevant advances were made regarding the Brazilian Labeling Program (PBE); products were rated according to their efficiency. The government also launched the energy efficiency certification program for commercial, public, and service buildings in 2009 and for residential buildings in 2010. In 2009, the certification of energy efficiency for vehicles was also created. Both the certification of buildings and vehicles are launched as part of the PBE, the former being the responsibility of Procel and the latter of Conpet.

Altoé *et al.* (2017) emphasize that another important regulatory milestone in the field of renewable energy and energy efficiency was Aneel's Resolution no. 482/2012. This resolution established a system of electricity compensation in Brazil (Net Metering), in which consumer units with distributed micro or mini generation (installed power up to 1 MW) from hydraulic, solar, wind, biomass, or qualified cogeneration sources, would be compensated. At the end of the month, the electric energy balance is calculated based on the energy injected into the grid and the energy consumed. If energy production is greater than consumption, credits are generated that can be used in up to 36 months. This resolution was updated in 2015.

3.4.2 EFFICIENCY DATA OF THE BRAZILIAN ELECTRICITY SECTOR

Table 2 shows data on commercial and technical electricity losses in Brazil.

Table 2 | Electricity Losses Data

	2014	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
Internal Electricity Supply (GWh)	624,341	615,628	619,697	625,727	636,397	651,329	645,952
Final Consumption (GWh)	532,559	524,749	521,376	538,063	538,403	545,373	540,189
Losses (Commercial and Technical) (GWh)	91,782	90,879	98,321	97,664	97,994	105,956	105,763
LOSSES (%)	**14.70%**	**14.76%**	**15.87%**	**15.61%**	**15.40%**	**16.27%**	**16.37%**

Source: EPE (2021).

Figure 4 shows the losses occurred in the period and the targets stipulated by the Brazilian government in the Paris Agreement.

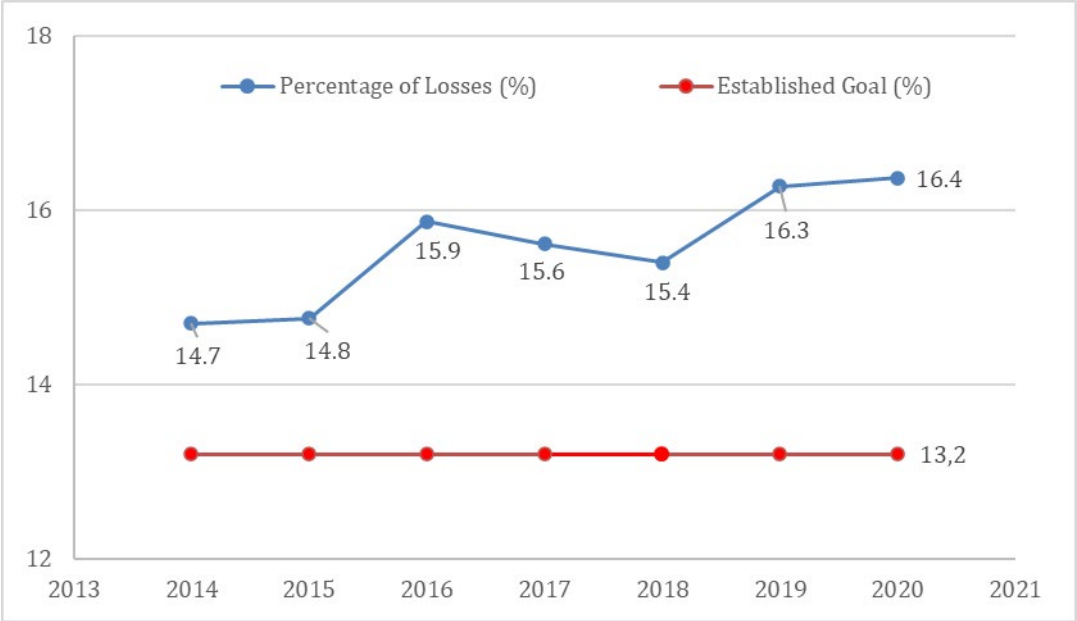

Figure 4 | Percentage of Electric Energy Loss in Brazil

Source: EPE (2021).

In relation to achieving 10% efficiency gains in the electricity sector by 2030, Figure 4 reveals that the percentage of electricity losses in Brazil grew from 2014 to 2016, decreased in 2017 and 2018, and increased again in 2020. In short, Brazil could not achieve the goal of being more efficient in the energy sector in no year after the ratification of the Paris Agreement.

Losses occur in the generation, transmission, and distribution of electric energy. According to the EPE (2021), the greatest losses occur in the transmission of energy between power generation and the distribution grid – losses that are inherent to the transportation of electric energy in the grid. To reduce losses, companies can use artificial intelligence to optimize shutdowns and start-ups to prevent unplanned downtime and to predict future maintenance requirements based on performance degradation (AHMAD *et al.*, 2021).

Altoé *et al.* (2017) report that to reach the electrical efficiency potential outlined in the 2030 National Plan, effective planning will be required to promote the rational use of electrical energy by the different economic sectors and by the population at large. The authors emphasize that the technical potential for efficiency gains is much higher and inclined to exploitation by implementing more aggressive incentive policies in electrical energy conservation.

3.4.3 WIND ENERGY AS A SOLUTION FOR REDUCING LOSSES IN POWER TRANSMISSION

Energy generation closer to consumption drastically reduces transmission and distribution losses (TOLMASQUIM, 2016). For Arantegui and Jänger-Waldau (2018), wind energy has the advantage that it can be implemented in a modular way almost anywhere on the planet. Off-grid small wind turbines can be used to provide electricity in remote areas. Due to the high population density in urban areas, both in emerging and developed countries, tailored energy solutions close to the areas where demand is generated are required (VALLEJO-DÍAZ *et al.*, 2022). López-González *et al.* (2020) evaluated technical performance in a desert climate on the Caribbean coast and in a dry-winter climate in the Andean mountains and concluded that the flat areas on the north coast have a low wind variability and high wind speeds, whereas in the Andes the implementation of SWT is limited by orography. Zhang *et al.*

(2020) demonstrated that wind energy is more economical and feasible than conventional electricity in the mountainous areas of southwestern China. Vallejo-Díaz *et al.* (2022) showed that although urban wind energy solution nowadays seems to be more expensive than the current electricity price in the Dominican Republic, the installation of small wind blades on the roofs of tall buildings results in a reduction of CO_2 emissions. Therefore, these tailored solutions could be included in each country's policies to combat greenhouse gas emissions. The use of small wind turbines should be beneficial to communities living in remote rural areas of Brazil, such as the Amazon and the *Pantanal*, as well as in urban areas, especially near the coastline. However, investments in research and development are needed to build the ideal type of wind turbine to meet the technical requirements of each location (wind speed and intensity, orography, among others). As described by Tolmasquim *et al.* (2021), the technological evolution of turbines is an important reason that led to the significant decline in wind energy prices, which brought new perspectives and potential to this kind of energy source and a reduction in installation costs.

In Brazil, all wind energy is generated by the onshore method. Onshore wind farms are the infrastructures that generate electricity from the wind blowing in onshore locations. On the other hand, offshore wind energy, still non-existent in Brazil, is the source of clean and renewable energy obtained by using the wind that blows offshore, where it reaches a higher and more constant speed due to the absence of barriers. Studies of offshore wind potential conducted by the EPE (2020) indicate that, at a 100 m height, Brazil's offshore potential is 697 GW at sites with depths of up to 50 meters, values that are much higher than the installed capacity in the country by December 2020 (17.75 GW). On August 22, 2018, Petrobras announced the development of the first offshore wind energy project in Brazil at the Guamaré hub in Rio Grande do Norte. However, in January 2020, the company notified the Brazilian Institute of Environmental and Renewable Natural Resources (Ibama – Brazilian acronym) –responsible for the project's environmental licensing in Brazil – that the pilot project was cancelled.

Implementing offshore wind farms can diversify Brazil's electricity matrix and allow power generation near large urban centres, reducing losses and transmission costs. This type of energy generation is growing rapidly in Europe and China. Kaldellis and Kapsali (2013) consider that the main reasons that drive this growth are the existence of stronger and more consistent winds in offshore locations, the absence of obstacles (*e.g.*, mountains, buildings, and trees) in marine environments, the low impact on communities, and the possibility of building offshore wind farms in coastal areas near large urban centres. The United Kingdom currently has the largest offshore wind capacity installed worldwide (GWEC, 2021) and the largest offshore wind farm – the London Array. Kaldellis and Kapsai (2013) mention examples of offshore wind farms that were installed near the coast and that have shown good potential in the UK. Scroby Sands Wind Farm is located at an average distance of 3 km from the coast and has an availability of 84.2%, and North Hoyle Offshore Wind Farm, which is located 8 km from the coast and has an availability of 91.2%. Artificial intelligence can help communication in real time among the various wind farm stations, to acknowledge the change in wind direction and wind speed, and to assess the grid's status (AHMAD *et al.*, 2021), allowing for a better coordination of the use of onshore/offshore wind farms in Brazil by the Brazilian Independent Transmission System Operator (ONS – Brazilian acronym).

3.5 ANALYSIS OF THE RESULTS OF PUBLIC POLICIES FOR WIND ENERGY IN BRAZIL

Since 2001, after the energy crisis, Brazil has been adopting policies to encourage the growth of renewable energy sources in the country. Figure 5 summarizes the main public policies that have benefited Brazil's wind power expansion.

Figure 5 | Main Public Policies for the Wind Sector in Brazil

Source: Brazil (2001), Brazil (2002), Luna et al. (2019).

3.5.1 EMERGENCY WIND ENERGY PROGRAM (PROEÓLICA)

Proeólica was created by Resolution no. 24 in 2001 by the Brazilian Chamber of Deputies for the Management of the Electric Energy Crisis (BRASIL, 2001). The objectives of the program were: 1) To enable the generation of 1,050 MW from wind sources integrated to the national integrated electric system by 2003; 2) to develop the use of wind power as an alternative energy source to promote socioeconomic and environmental development; 3) to help compensate seasonality in the hydrological flows of reservoirs of the National interconnected system.

Incentive program for alternative sources of electric energy (Proinfa)

The Proinfa was created by Federal Law no. 10,428 on April 24, 2002 (BRASIL, 2002), and regulated by Decree no. 4541 on December 23, 2002, aiming to increase the participation of electric energy produced by undertakings of Independent Autonomous Producers. The program's target was wind farms, small hydroelectric plants, and biomass plants.

3.5.2 EXCLUSIVE AUCTIONS FOR WIND ENERGY

Since 2009, wind energy has been marketed in a regulated environment by specific auctions for renewable sources. Wind energy has economic-related characteristics such as high initial investment, low operating cost, and a seasonal and intermittent production flow, which were formulated into a contractual model to consider the average production over the years and to allow readjustments and

compensations according to generation patterns over time. This change in the contracting system stimulated the development and growth of wind energy in Brazil (LUCENA, J. de A. Y.; LUCENA, K. Â. A., 2019). The authors also emphasize that the economic crisis Brazil experienced in 2015 resulted in a drop in electricity consumption and, consequently, a reduction in wind energy contracting in 2015, even with the three auctions that happened that year. In 2016, there was no contracting of wind energy.

3.5.3 OTHER GOVERNMENT PROGRAMS

Luna *et al.* (2019) analyzed other programs and tax incentives created by the Brazilian government over time, which aimed to encourage the generation of energy from renewable sources. On December 15, 2015, the Brazilian Ministry of Mines and Energy launched the Program for the Development of Distributed Generation of Electricity (PROGD) with the objective of deepening actions to stimulate consumer energy generation (residential, commercial, and industrial). The ICMS Agreement 101/97 grants tax exemption on operations with equipment and components for using solar and wind energy (solar heaters, photovoltaic generators, and wind power turbines). In November 2015, the Ministry of Agrarian Development (MDA) included the financing of equipment for solar and wind energy production in the Mais Alimentos Program – benefitting family producers with lower interest rates.

As described by Lima *et al.* (2020), the Brazilian government has been holding specific energy auctions for renewable technologies (solar and wind). Tolmasquim (2016) recognizes that Brazil's continental characteristics and its geographic location are important points for the use of the wind source, allowing for the implementation of wind farms located in different regions with different wind regimes and also, the capacity of wind farms winning energy auctions have been higher than the global average values. Additionally, these authors report that the growth in the participation of renewable resources in the Brazilian electricity matrix – such as wind and solar sources – contributes to solving stability and supply capacity issues.

3.5.4 POLICY OUTCOME: THE GROWTH OF WIND ENERGY IN BRAZIL

In December 2000, the year before Brazil suffered the energy crisis, the installed wind power capacity was only 20 MW (ANEEL, 2002). Figure 6 shows how the installed capacity of wind power plants has evolved in Brazil from 2014 (one year before the signing of the Paris Agreement) to 2020.

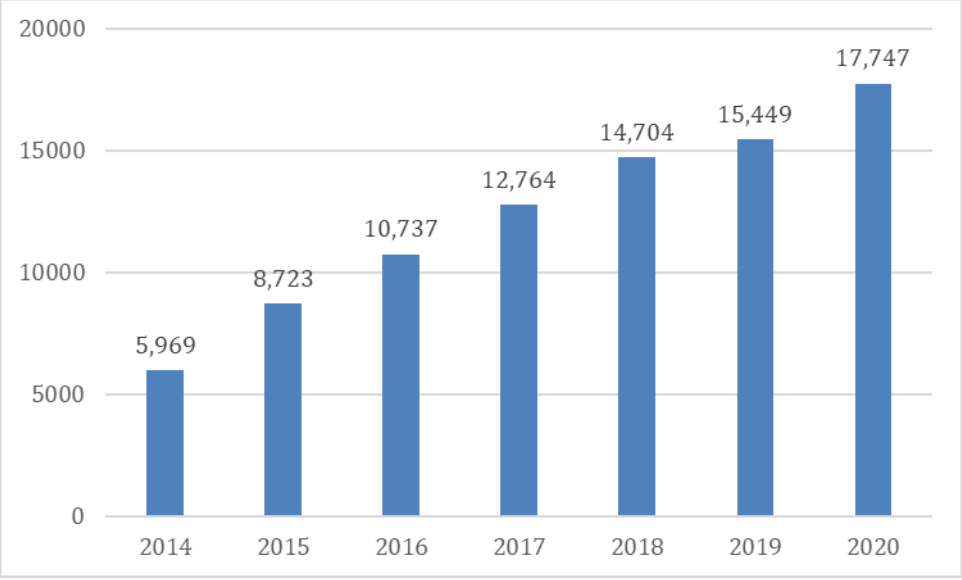

Figure 6 | Evolution of the installed capacity in wind power plants in Brazil (MW)

Source: Abeeólica (2021).

In December 2020, wind power plants in operation totalled an installed capacity of 17,747 MW. According to the Gwec (2021), Brazil ranked seventh in 2020 in the world ranking of accumulated onshore wind capacity. Brazil appeared in third place in the ranking that accounts explicitly for new capacity installed in the year, having a new installed capacity of 2,298 MW in 2020. For Lozornio *et al.* (2017), Brazil has advanced in using wind energy mainly due to the adopted incentive policies.

Notably, the installed capacity increased by approximately three times from 2014 to 2020, going from 5,969 MW to 17,747 MW, representing a significant average growth rate of 20% per year. According to Abeeólica (2021), 57,000 GWh of wind energy were generated throughout 2020. The five states with the highest wind generation in 2020 were Bahia (16,220 GWh), Rio Grande do Norte (15,590 GWh), Ceará (5,950 GWh), Piauí (5,910 GWh), and Rio Grande do Sul (5,810 GWh).

Abeeólica (2021) emphasizes that the wind source contributes so that Brazil achieves the goals for the Brazilian electricity sector. Since wind energy is a CO2-free source, it can replace other sources of electric energy generation, reducing emissions. In 2020, 21.2 million tons of CO2 were avoided, equivalent to the annual emission of about 21 million passenger cars. Wind energy growth could help Brazil achieve emission reduction targets assumed by the government in the Paris Agreement because of the greenhouse gas emission reductions it brings (RAIMUNDO *et al.*, 2018).

3.5.5 NEW POLICIES FOR WIND ENERGY GENERATION AND TRANSMISSION ARE NEEDED

To meet the Paris Agreement and the Sustainable Development Goals, nearly all countries need to urgently and drastically increase their climate action (HÖHNE *et al.*, 2020). Accounting for health and climate costs in energy planning would provide an economic justification for decarbonizing energy systems, as well as reduce the social cost of supplying electricity, boost the economy, and improve the quality of life (HOWARD *et al.*, 2020).

Brazil's electricity production and transmission system is a large-scale hydro-thermo-wind system with a predominance of large hydroelectric power plants (TOLMASQUIM *et al.*, 2021). Despite the notable advances in the expansion of wind energy in Brazil, creating new incentive policies is necessary to ensure the continuity and security of the electricity supply in the country. The largest installed capacity for electricity generation in Brazil still originates from hydroelectric plants. Although in 2001, hydroelectric plants represented 83% of installed capacity, in 2020, they represented 62% (IEA, 2021). However, the country went through a critical hydrological scenario in 2021 with the lowest flows since 1930. Although all regions of Brazil have reservoirs, the main ones are concentrated in the Southeast/Midwest subsystem, representing 70% of the country's storage capacity (MME, 2021). In a scenario of low reservoir levels, together with the low prospects for rainfall in a scenario of economic growth, there are reasons for concern, considering the possibility of a new energy crisis as that of 2001. As a way of containing the risk of new blackouts, the Power Sector Monitoring Committee created by the government had to resort to activating thermoelectric power plants. A crisis-preventing solution includes managing operating restrictions of the hydroelectric plants to preserve the levels of the reservoirs; management for the availability of fuel for thermoelectric plants; management for the start-up of operation of new plants and transmission lines and campaigns for conscious and rational consumption of water and electric energy (MME, 2021). However, these are short-term measures. No law was enacted to increase the incentive for the generation of alternative renewable energy sources, which could benefit the country in the long term.

On the other hand, the need for investments in the country's transmission lines is evident. The Brazilian electricity system has experienced congestion in the Northeast region, affecting the coordinated transmission expansion and new wind power capacity (HERRERA; DYNER; COSENZ, 2019). New farms cannot connect to the grid in some states due to current grid capacity limitations and low availability of substations and high voltage lines near potential windy sites (DIÓGENES *et al.*, 2020). Transmission

grid issues are the main reason for the delay of such projects in Brazil. This suggests that coordination between the expansion of renewable energy and the expansion of the transmission system should be a core element of the auction design (BAYER; BERTHOLD; FREITAS, 2018). However, the federal government has shown less commitment to meeting the Paris Agreement's goals on carbon emissions (PONTES, 2020; THOMAS, 2021), which represents a potential barrier (MARTINS; PEREIRA, 2011).

4 CONCLUSION

Based on this study, we can conclude that public policies of tax incentives for wind power generation in Brazil – after the 2001 electricity crisis – are responsible for the increase in investments in wind power generation. Additionally, they allowed the diversification of the electric matrix via a renewable, low carbon emission, and abundant source in the country. As a result, the policies have been contributing to help to solve the national electricity problem and making the country fulfil the commitments made in the Paris Agreement and SDG 7. However, this process is still in progress; there still needs to occur a strong governmental interest and/or commitment in the expansion of sustainable energy generation. The need to invest in renewable sources in Brazil, besides wind power, goes beyond the need to comply with international agreements; it is a question of meeting the internal demands of residential, commercial, and industrial consumers. As the Brazilian agribusiness sector is one of the strongest in the world, a new blackout could affect the domestic market and other countries' supply.

Despite the growth of renewable sources in the electricity matrix in recent years, more government incentives must be created and enacted for this sector. Besides, investments in research and development are needed for wind turbines suitable for other regions of Brazil besides the Northeast, as well as to address the small turbine market. The incentive to decentralize and expand wind turbine generation with resources once used for developing fossil energy sources infrastructure also presents itself as a great opportunity.

Additionally, the public policies created so far have been unable to reduce electricity losses in Brazil by 10% of what they were in 2014 (to improve electrical efficiency). It is argued that offshore wind power generation – so far non-existent in the country – is an option that should be considered to increase the share of renewable energy in the national electric matrix, diversify energy sources, and especially reduce electrical losses caused in transmission – increasing electrical efficiency. Therefore, specific tax incentives should be offered for this type of energy generation.

Future studies could assess what public policies other countries implemented to diversify the electricity matrix and thus achieve the goals set out in the Paris Agreement and whether these policies enable these countries to improve electricity efficiency.

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Disputes and narratives on the distributed generation of electricity in Brazil: setbacks for the 2030 Agenda for sustainable development and the Paris Agreement

Disputas e narrativas sobre o marco da geração distribuída no Brasil: retrocessos para a Agenda 2030 e o Acordo de Paris

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ABSTRACT

Centralization and low diversification of the Brazilian electricity matrix have increased the feeling of energy insecurity. In the face of climate change, this problem is gaining greater proportions. The present research analyzed the political arena around the regulation of distributed electricity generation to clarify expansion obstacles. To this end, documents, speeches, interviews, presentations, audiovisual material, and press publications about the country's distributed generation and solar power were analyzed. Results indicated that, despite the great development potential of the source in the country and the international commitments signed, the identified coalitions dispute narratives that result in setbacks for climate and sustainable development agendas.

Keywords: Aneel. Solar energy. Decentralization. Sustainability Agendas.

RESUMO

A centralização e a baixa diversificação da matriz elétrica brasileira aumentaram a sensação de insegurança energética no país, um problema que ganha proporções ainda maiores diante das mudanças globais do clima. Esta pesquisa analisou a arena política em torno da regulamentação da geração distribuída de energia elétrica a fim de elucidar os entraves à sua expansão. Para tanto, foram analisados documentos, discursos, entrevistas, apresentações, material audiovisual e publicações na imprensa sobre a geração distribuída e a fonte solar no país. Os resultados da pesquisa indicaram que, apesar do grande potencial de desenvolvimento da fonte no país, e dos compromissos internacionais firmados, as coalizões identificadas disputam narrativas que resultam em retrocessos para as agendas do clima e do desenvolvimento sustentável.

Palavras-chave: Aneel. Fonte Solar. Descentralização. Agendas da sustentabilidade.

1 INTRODUCTION

Solar energy is an inexhaustible source of resources, which presents great electrical potential in Brazil, a country possessing extraordinary levels of solar irradiation, even in less sunny locations (JEAN *et al.*, 2021; PEREIRA, 2017). However, although the installation of photovoltaic systems has represented a 33% increase over the years 2019 and 2020, public policies and regulation standardization on the use of the solar source have not yet been able to reach the Brazilian generation potential. This gap has been discussed since the Brazilian Electricity Regulatory Agency (Agência Nacional de Energia Elétrica – Aneel) Normative Resolution (NR) Nº. 482/2012.

From NR Nº. 482, consumers have been authorized and encouraged to generate their own energy by installing photovoltaic systems. With the resolution, the surplus production returned to the public distribution network, converted and compensated in credits in the consumer's electricity bill. This surplus was injected and stored back into the grid for use by other nearby consumers, operating as a battery for these systems. Every 1 kW/h produced by the consumer's system was offset by 1 kW/h from the distribution network.

The rules established in NR Nº. 482 underwent two revisions until 2017. The first aimed to readjust and update the electrical capacities supplied by Distributed Generation (DG) in the country, resulting in NR Nº. 687/2015. The second review, in 2017, gave rise to NR Nº. 786, which updated the definitions of distributed minigeneration and the framework for distributed microgeneration or minigeneration. The third revision began in 2018 (RUBIM, 2021), and its process was marked by polarized discussions between supporters of the advancement of solar energy in Brazil and opponents of the incentives generated by the Electrical Energy Compensation System (EECS) introduced by the respective regulation (Figure 1).

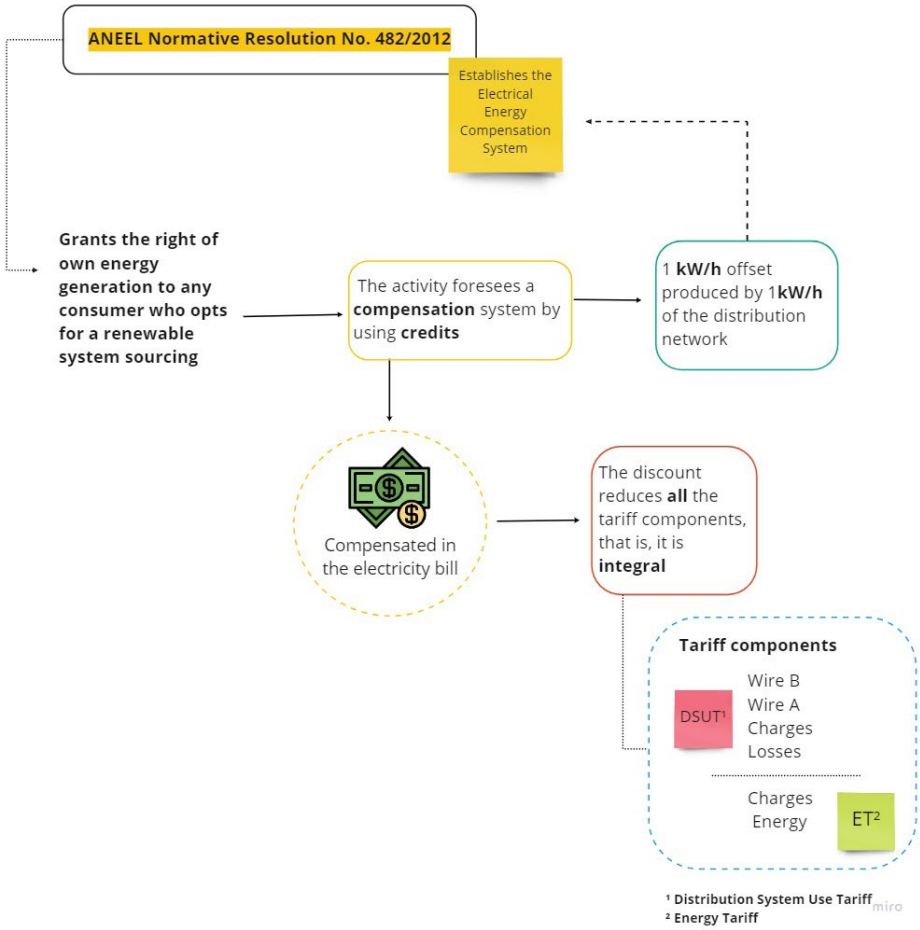

Figure 1 | Summary diagram of the main rule established by Aneel NR No. 482/2012

Source: Own elaboration.

Despite the advances provided by NR Nº. 482, as of 2015, questions have emerged about the form of compensation provided by the EECS, mainly because this system does not consider the costs of the "use" of the utilities' network. From this, Aneel elaborated six proposals for revising the normative, presenting setbacks concerning the NR. In light of this, the electric sector and civil society have mobilized around the social and environmental benefits that the expansion of the sector offers to society. The debate went to the National Congress as Bill of Law Nº. 5829.

In January 2022, the subject was discussed definitively, giving rise to the regulatory framework for distributed generation. Law 14300/2022 established a partial compensation system in which the consumer will pay for the surplus injected into the grid. However, the law allows all photovoltaic systems installed before January 2023 to enjoy the old EECS rules until 2045.

Based on this, this paper aims to describe the political arena, the narratives and disputes that influenced the regulatory framework for distributed generation in Brazil and its interaction with the 2030 Agenda for sustainable development and the Paris Agreement.

2 METHODOLOGY

The data analysis of this work was based on two stages: i) gathering of written and audiovisual materials on the subject of solar energy in Brazil; ii) characterization, positioning, classification and division of the actors based on their main agendas and arguments.

The gathering of materials sought to understand the context of the discussions about the issue and to subsidize the identification of the main arguments and groups active on the matter. The more than 80 materials collected on the *internet* contained positions and statements about DG and solar sources between 2018 (Third revision of NR Nº. 482) to 2022 (DG regulatory framework in Brazil - Law 14300). These materials were fully transcribed for identification, classification, and analysis in this paper.

The collected materials made it possible to identify the positioning and arguments presented by each actor in the materials. Throughout the analysis, 80 actors were identified and based on the criterion of highest Absolute Frequency (AF) of citations in the collected materials, seven were prioritized for analysis in this study, namely: (i) Aneel; (ii) Prosecution Office (Ministério Público – MP); (iii) Brazilian Photovoltaic Solar Energy Association (Associação Brasileira de Energia Solar Fotovoltaica – Absolar); (iv) Federal Court of Accounts (Tribunal de Contas da União – TCU); (v) Civil Society – Free Solar Organization (Movimento Solar Livre Association – MSL), National Institute for Clean Energy (Instituto Nacional de Energia Limpa e Sustentável – Inel), Climate Observatory (Observatório do Clima – OC) and Revolusolar Foundation; vi) Chamber of Deputies – Congressmen Beto Pereira, Rodrigo Agostinho, Lafayette de Andrada and Marcelo Ramos; and vii) the President of the Republic, Jair Messias Bolsonaro.

Based on the reading of the analyzed materials, two main groups were identified: i) in favour of the rules of NR Nº. 482; or ii) against the rules of NR Nº. 482. From this point, these actors were described in their respective groups and main arguments.

3 RESULTS

3.1 CHARACTERIZATION, POSITIONING, CLASSIFICATION AND DIVISION OF THE ACTORS

3.1.1 BRAZILIAN ELECTRICITY REGULATORY AGENCY (ANEEL)

Aneel is a special regime autarchy linked to the Ministry of Mines and Energy (MME), which aims to regulate the Brazilian electricity sector (ANEEL, 2022), including the DG and distributed microgeneration modalities.

Aneel established the general conditions for distributed generation in 2012, with NR Nº. 482. This regulation allowed the connection of a self-generation system from renewable sources to the distribution networks of the utilities. This process marked the advance of solar energy in Brazil. In 2015, Aneel revised the normative and applied new rules that further boosted the use of the solar source in the country, giving rise to NR Nº. 687/2015.

However, despite the update working as an incentive policy for solar energy in Brazil, the Resolution already foresaw the revision of these rules. Therefore, in 2018 Aneel started the third cycle of revising the regulations of Nº. 482 and Nº. 687 to reevaluate the established rules.

From these debates, Aneel prepared six proposals to amend NR Nº. 482 and opened a Public Consultation (PC) Nº. 10/2018 to discuss the proposals presented. The debate generated a Regulatory Impact Assessment (RIA) – Nº. 04/2018 – which culminated in several public hearings, recommendations and studies about the EECS.

In 2019, Aneel opened a new PC – Nº. 025/2019 – with preliminary wording for the Resolution. The wording followed proposal Nº. 6 – the most stringent option for EECS – and differed from the main discussions and recommendations of the previous PC. In this proposal, the EECS would compensate 1 kW/h produced by the consumer for 0.3 kW/h injected into the distribution network.

Industry players and civil society did not accept the PC and the proposal presented. In turn, Aneel did not legitimize the arguments presented and positioned itself against maintaining the current EECS established by its own regulation Nº. 482 of 2012.

3.1.2 PROSECUTION OFFICE (MP)

The MP has an independent and autonomous role, assured by the Federal Constitution, in subjects of public interest.

In October 2019, the MP intervened in the Aneel review process by establishing an Administrative Procedure (AP). The AP intended to "monitor and examine the regularity (...) of Public Consultation Nº. 025/2019, which aims to revise Resolution Nº. 482" (MPF, 2019). As a result, the MP requested clarifications about the revision from the MME and Aneel. Furthermore, in a complementary way, it requested Absolar a study on the losses generated for society from the changes proposed by Aneel (MPF, 2019).

In November 2019, the MP issued seven official recommendations to Aneel. In the document, the MP emphasized the public administration's duty and responsibility in situations of abuse of regulatory power, which may favour economic groups, cost increases without proof of direct benefits, and interfere with the arrival of new competitors in the markets.

The MP judged the rules established by NR Nº. 482/2012 as "a pioneering and fundamental regulatory framework for the development of the distributed microgeneration and minigeneration electricity sector" (MPF, 2019), being a driver of an industry that is a creator of jobs, development, and independence of electricity supply.

About the EECS established by NR Nº. 482, the MP pondered that the rule enables electricity generation without needing public capital investment. In addition to being able to "pulverize in the national territory, the generation of distributed, clean, inexhaustible and environmentally friendly electricity" (MPF, 2019). Also, according to the MP, "the system is invaluable for fostering an activity that aims at the independence of civil society, even if partial, in relation to public services" (MPF, 2019).

The MP also recognizes that the solar source is:

> a fully renewable, inexhaustible, alternative source for the challenges of expanding energy supply. Especially with regard to low environmental impacts and the desire for diversification of the Brazilian electricity matrix (MPF, 2019).

In addition to also recognizing the benefits of distributed generation, which rely on the production of energy nearby consumption, reduced use of thermoelectric plants and transmission lines, reduced pressure on distribution networks, and "minimizes investments in generation, transmission, and distribution of electricity, in addition to reducing losses" (MPF, 2019).

Finally, the MP understood that the new proposal would generate legal uncertainty for investors, consumers, and individual and collective losses. Furthermore, the MP also alleged that Aneel's new proposal is divergent from Brazil's National Energy Policy – Law Nº. 9478 of 1997.

The MP positioned itself in favour of maintaining the rules established in NR Nº. 482/2012 by recognizing the social, economic, and environmental advances that this type of generation promotes.

3.1.3 BRAZILIAN PHOTOVOLTAIC SOLAR ENERGY ASSOCIATION (ABSOLAR)

Absolar was a protagonist in the discussions about the theme, represented by Bárbara Rubim – Vice-President of Distributed Generation –and Rodrigo Lopes Sauaia – Executive President. Absolar's participation brought recommendations to Aneel with technical, economic, social, and environmental analyses on the contributions of solar energy to society (SAUAIA, 2021).

According to Absolar, the photovoltaic sector has generated more than 233,000 jobs for Brazilians and has moved more than 39.8 billion reais in new investments since 2012. In public terms, the sector collected more than 11.6 billion reais in taxes and avoided the emission of more than 1.1 million tons of carbon dioxide gas (BAITELO, 2021).

In light of this, Aneel refused to assess the arguments presented as it did not consider the issue within Aneel's regulatory competence. From this, Absolar and other interested parties have mobilized for NR nº. 482 to become a Bill of Law in the National Congress. The proposal sought a milder change than the one presented by Aneel.

Since the debates onset, Absolar has also positioned itself in favour of establishing a regulatory framework for the sector, which would generate more legal certainty for its development. According to Rodrigo Sauaia:

> Solar energy is a technology [...] that creates jobs and develops new projects, attracting new investments and not dependent on public sector investments. The DG, for instance, is a decision from the consumer.

> It is the consumer him/herself who invests in solar energy and undertakes this investment, irrigating the economy of the country and his/her own economy in terms of electrical energy. And the saving of this resource [...] will be used in the application of other consumptions, such as food, health, education, which are injected in the economic recovery of the country (SAUAIA, 2021).

Absolar is in favour of maintaining the rules established in NR. 482/2012.

3.1.4 FEDERAL COURT OF ACCOUNTS (TCU)

The TCU "is an external control body of the federal government, which monitors the country's budgetary and financial execution" (TCU, 2022).

The TCU enters the debate on NR Nº. 482 from the MP's request for clarification on possible Aneel violation of legal certainty and good faith of public consultation instated in 2019.

The MP's representation requested that Aneel freeze the public consultation process until the body can judge the issue. At the time, the TCU understood that there was no merit in the precautionary concession. However, it saw the request as an opportunity to "exercise control over a sensitive issue for the electricity sector.

Based on the studies presented by the requested parties, the TCU dismissed the MP's representation and judged the PC in question as "regular and under the principles of legality, legitimacy, reasonableness, legal certainty and good faith". (TCU, 2020).

The court recognized the importance of the EECS contained in NR Nº. 482/2012 for the advancement of distributed mini and microgeneration in Brazil, however, they identified:

> a cross-subsidy policy among electricity consumers of a regressive nature in terms of the income distribution, which has put pressure on the tariff of consumers with lower purchasing power and made spending by consumers with higher income less expensive (TCU, 2020).

In addition to the argument about the expenses with the EECS, the TCU also raised the hypothesis that NR Nº. 482/2012 breaches the General Law of Concessions by authorizing the tariff differentiation for electricity consumers with DG and those who do not. The agency alleges discriminatory treatment of consumers and illegal instruments of regulation. It also reports that the current system "generates negative externalities for other consumers and the electric power utilities" (TCU, 2020), generating economic inefficiencies and going against the precepts of social justice. According to the report, these factors become a "death spiral" for power distributors, as they compromise the future revenue collection of the distributors (TCU, 2020).

The report also requested that the information in the process be shared with the Chamber of Deputies, the Federal Senate, and other authorities involved in the discussion of bills going through the National Congress.

The agency considered unfounded the representations presented and determined the removal of the tariff differentiation present in NR Nº. 482/2012. Thus, the agency is against maintaining the current electrical compensation system established by NR nº. 482.

3.1.5 CLIMATE OBSERVATORY (OC)

The OC is a coalition of major civil society organizations created in 2002 to discuss the effects of climate change.

The OC also engaged in the debate to maintain the rules contained in NR nº. 482. It also emphasizes the importance of society and organizations' engagement in favour of solar energy advancement, as highlighted in the following excerpt:

> [...] the population, public opinion, has to be very mobilized to demand from the government that Brazil realize its energy and climate potentials and be an example to the world, which would also do a lot of good for our economy and each of us Brazilians (ASTRINI, 2022).

According to the OC, Brazil stands out for its capacity to generate solar energy precisely because it has great potential due to the high level of irradiation the country receives all year round (ASTRINI, 2022). Despite this, Márcio Astrini, executive secretary of the OC, states that investments and public policies for the theme are lacking (ASTRINI, 2022).

3.1.6 NATIONAL INSTITUTE FOR CLEAN ENERGY (INEL)

Inel "is an intelligence centre to support efforts for clean and sustainable energy sources" (INEL, 2022). Moreover, it aims to "promote the democratization of access to clean and cheaper energy to the whole society" (INEL, 2022).

According to Rodrigo Pinto, an Inel consultant, if the normative update were to be implemented, solar investments in Brazil would become economically unfeasible and legally uncertain. According to Rodrigo, "it is shameful for Brazil the contribution of solar today, in relation to the contribution of other more expensive sources, such as nuclear and fossil" (PINTO, 2021).

Concerning EECS, the Inel consultant clarifies that "an intelligent public policy would be a public policy that encourages the DG producer to insert its energy in the local distribution network" (PINTO, 2021), given its various economic benefits, both in terms of production, distribution and electricity losses. For Rodrigo, the revision of the normative and the approval of Aneel's proposal No. 6 "takes a path contrary to an intelligent public policy because it tries to limit Brazilians to invest in solar panels" (PINTO, 2021).

3.1.7 FREE SOLAR ORGANIZATION (MSL)

MSL is an Association representing several companies in the sector, faculty and student collectives, and society itself. Its main goal is the "democratization of clean and renewable energy in Brazil and free access to solar energy" (MSL, 2022).

MSL has engaged in the issue by seeking to disseminate the review proposals and broadening society's participation in discussions on the topic. MSL has declared itself against Aneel's proposal Nº. 6, translated as against "taxing" the sun. From the social engagement promoted, the expression "taxing the sun" became the great slogan of the trend against Aneel's revision.

According to MSL, "taxing the sun" "is absurd, since solar energy has such a low penetration in Brazil" (NETO, 2021) and is not justifiable, especially in light of a law for universal access to energy.

3.1.8 REVOLUSOLAR FOUNDATION

Revolusolar Foundation is "a non-profit association [...] that has the purpose of promoting the sustainable development of low-income communities through solar energy" (REVOLUSOLAR, 2022).

Revolusolar classified the proposal presented by Aneel as: "absurd, which taxes by about 60%, bypasses the industry's contributions and puts at risk the legal certainty and regulatory predictability of those who have invested in the DG segment since 2012" (REVOLUSOLAR, 2021). In addition, the Foundation also exposes unease about the investments and subsidies applied to fossil fuels and "large plants that are harmful to the environment and communities" (REVOLUSOLAR, 2021).

Faced with the implications that the change in NR Nº. 482 could generate in the sector, the Foundation engaged in the movement "#TaxarOSolNão" (#NoTaxingTheSun) and stood out to civil society as an active agent.

3.1.9 CHAMBER OF DEPUTIES

The Chamber of Deputies received the registered requests for a Bill of Laws to transform NR Nº. 482 into a specific law and, during the debates, received more than 100 drafting proposals, parliamentary amendments, and other documents referring to the matter. The various protocols presented proposals for the officialization of the EECS as established by NR Nº. 482 and for the institution of stricter forms of charging for distributed generation users.

In this debate of almost four years, the deputies Silas Câmara, Marcelo Ramos, Lafayette de Andrada, Beto Pereira and Rodrigo Agostinho had the greatest prominence in the discussions.

Congressman Silas Câmara, affiliated with the Republican Party for the State of Amazonas, was the author of the Bill of Law 5829/2019. The initial proposal sought to "Establish the legal framework for distributed microgeneration and minigeneration, the EECS and the Social Renewable Energy Program (Programa de Energia Renovável Social – PERS)" (BRASIL, 2019). According to Silas, the Bill of Law has the potential to "save another 300 billion reais in terms of investment [...] and create more than a million jobs in Brazil" (CÂMARA, 2021). In addition, the deputy believes in the investment power that the regulatory framework can bring to entrepreneurs in terms of solar panel manufacturing and in relation to creating new jobs.

The negotiations in the Congress about Bill of Law 5829 have started to become more frequent since the discussions have advanced. Then, in 2021, Congressman Lafayette de Andrada was appointed rapporteur for the bill. Since then, the deputy has sought to reconcile the main proposals presented to the house, seeking agreements with both "sides" of the debate. Over the years of discussion, Lafayette has opened dialogues for maintaining the current EECS rules for old users while decreasing the compensation ratio for new users.

Marcelo Ramos, Federal Deputy of the State of Amazonas, on the other hand, during the proceeding of Bill of Law 5829/2019 affiliated with the Liberal Party (PL), was against maintaining the compensation rules established by NR Nº 482 during all the years of discussion on the issue. Due to his strong performance in the discussions, he became the main representative against incentives for distributed generation in the Legislative Branch.

The deputy claims that there is no legal provision for the EECS established by NR Nº. 482 and that this system is configured as a "subsidy" to these self-generators, equally without legal support for it to occur. These arguments are based on the conclusions presented by the TCU.

According to the deputy's understanding, the then "subsidy" established by Aneel is harmful to electrical consumers who do not have distributed generation because it makes these consumers pay for the tariffs of DG users. In his several pronouncements, Marcelo Ramos also exposes his opinion about "taxing" the sun, an expression that characterized the debate about NR Nº. 482:

> [...] I want to first restore truth and rationality to this debate. Actually, nobody is discussing taxing the sun; what we are discussing is to stop taxing the poor to pay for the rich's energy. The subsidy that exists today in DG is a real Robin Hood policy in reverse [...], for those who cannot afford to hire DG and put solar panels to pay part of the bill of those who can, which are the people with higher purchasing power [...]. (RAMOS, 2021).

During the proceedings in the Chamber of Deputies, until the regulatory framework was established, Marcelo Ramos presented himself as a defender of the end of the EECS and the "poor" non-DG users:

> The big problem is who can afford a solar power panel for their own generation. The poor cannot. And when the middle class and upper-class switch to solar power and stop paying the wire bill, that bill goes to someone else. Goes to whom? For the captive consumer, which is the poor who cannot afford a solar power board (RAMOS, 2021).

On the other hand, Congressmen Beto Pereira and Rodrigo Agostinho were supporters of the EECS established by NR Nº. 482, and for this, they presented specific Bill of Laws and amendments to Bill of Law 5829. In addition to publicly positioning themselves in discussion and decision-making spaces in the Chamber of Deputies. For Congressman Beto Pereira:

> [...] Aneel, in 2019, had the pretension in a single, exclusive, unilateral measure to devastate the whole sector. That measure, which this house rebelled against, would make any investment in renewable energy unfeasible in this country (PEREIRA, 2021).

The Congressman also questioned the presence of the Minister of Mines and Energy during the plenary sessions held on the subject and in the hearings of the Consumer Defense Commission – where the issue was also discussed. Beto Pereira highlighted the importance of a representative of the Federal Government in the debates since the Chambers of Deputies and society need to know the government's position on the Brazilian energy policy and the country's plans for renewable energy.

Given his constant involvement with the theme, the Congressman presented to the Chamber of Deputies the Bill of Law 2215/2020, which aimed to change "Law Nº. 9074, of July 7th, 1995, to establish the Electrical Energy Compensation System (EECS)" (BRASIL, 2020). The Bill of Law was attached to Bill of Law 5829/2019 and started to be discussed by the rapporteur Lafayette de Andrada.

In the same way, Congressman Rodrigo Agostinho actively participated in constructing the Bill of Law 5829/2019. For Agostinho, the theme is of national interest, and developing this public policy is fundamental for improving clean energy in Brazil. Still, according to him, it will be essential that the defenders of the sector unite because "people will not want to give up the thermoelectric plants, the rotten coal industry. We are going to have to confront and have our agenda with a lot of unity and move this forward" (AGOSTINHO, 2020).

The Congressman proposed eight amendments to the project's text in this sense. The rapporteur rejected five of these eight because they were already contemplated in the adjusted project proposal. Highlight to amendment 21 that proposes the reduction of the payment price for the Distribution System Use Tariff (DSUT) Wire B, considering a term staggering on the amount paid (RUBIM, 2021).

In addition to these contributions, Bill of Law 5829 received another 59 amendment proposals among opponents and supporters of the EECS. At the end of two years of discussions, textual adjustments, and amendments by the Federal Senate, Bill of Law 5829 had its final wording on 12/17/2021. The final wording became Law Nº. 14300/2022 on 01/07/2022.

Law Nº. 14300 maintained the rules established by NR Nº. 482/2012 on the EECS for all consumers already connected to the grid and for new projects until January 2023. For these consumers, the

current rules will be maintained until 2045. New consumers connected to the grid, as of 2023, will have the energy generated partially compensated. These new projects will now pay part of the Wire B (the tariff that pays the distributors) or part of the Wire A (the tariff that pays the transmitters). What is new about these fees is that they will be staggered over the course of each year.

Despite the unanimous vote on the final wording of Bill of Law 5829, Congressmen Marcelo Ramos and Lafayette de Andrada understood that the EECS is "fairer" than what was foreseen in NR Nº. 482, although they believe that the incentives to the system should have been reduced or even excluded.

Similarly, EECS advocates understand that the Law is more flexible and advantageous for advancing solar energy than the proposed revision presented by Aneel. Although it was also not the most compatible with Brazil's current energy situation and with the commitments made by the 2030 Agenda and the Paris Agreement.

3.1.10 PRESIDENCY OF THE REPUBLIC

In view of the debates about the revision of the normative, Bolsonaro has manifested himself against the proposal for revision of NR nº. 482 presented by Aneel. According to the President, his government is against taxing the solar source, although he is aware of Aneel's autonomy to regulate the subject.

Given the regulations revision developments, Bolsonaro met with the President of the Chambers of Deputies at the time, Rodrigo Maia, and with the President of the Senate, Davi Alcolumbre, to discuss the issue. The agreement between the parties was to prevent the approval of Bills that would establish the taxation of solar energy and the withdrawal of the current EECS rules.

After almost three years of discussions, and with the request for urgency for the negotiations on the subject in Congress, the Bill 5829/19 was sanctioned by Bolsonaro, originating Law 14300/2022.

3.2 IDENTIFICATION AND COMPOSITION OF THE EXISTING GROUPS

The analyzed actors are organized into two groups: Group 1 – in favour of the rules established in NR No. 482/Aneel, and Group 2 – against the rules established in NR Nº. 482/Aneel.

Group 1 comprises Absolar, MP, President of the Republic, Congressmen Beto Pereira and Rodrigo Agostinho, OC, Inel, Revolusolar, and MSL (Table 1).

Table 1 | Composition, Representation, and Main Arguments of Group 1

GROUP 1 *In favour of the Rules established in NR no. 482/Aneel*				
Actor	*Society Sector*	*Representation*	*Main Arguments*	*Main interests*
Absolar	3rd Sector	Solar sector (companies, manufacturers, academia, freelance professionals, institutions)	The maintenance of the rules stimulates Brazil's solar irradiation potential, the reduction of electric losses, and social advances	Expansion of the solar source in the electric sector
MP	1st Sector	Society	The rules established in the resolution present environmentally friendly market solutions	Defence and protection of the environment and the consumer's vested right

GROUP 1 *In favour of the Rules established in NR no. 482/Aneel*				
Actor	*Society Sector*	*Representation*	*Main Arguments*	*Main interests*
Jair Bolsonaro	1st Sector	Country	The solar source needs to be stimulated by the government	Record expansion of the solar source during the years of his government. Intending to have the solar source as the pre-salt of his government.
Beto Pereira	1st Sector	State of Mato Grosso	Investments in renewable energy are the best way forward and bring greater balance to environmental issues	Maintenance of rules for greater legal certainty in solar investments. Environmental advocacy in favour of the commitments outlined in the Agenda 2030 and the Paris Agreement.
Rodrigo Agostinho	1st Sector	State of São Paulo	The maintenance of the rules expands and favours investments in solar energy, which decreases the dependence on fossil fuels	Maintenance of rules for greater legal certainty in solar investments. Environmental advocacy in favour of the commitments outlined in the Agenda 2030 and the Paris Agreement.
OC	3rd Sector	Coalition of Brazilian Civil Society Organizations	The maintenance of the rules stimulates the Brazilian capacity for clean energy generation and benefits the country's economy	Environmental advocacy in favour of the commitments outlined in the Agenda 2030 and the Paris Agreement. Acting on the topic of climate change.
Inel	3rd Sector	Transport sector, households, agriculture, industries and commerce	The contribution of solar energy should be stimulated to be larger than the fossil and nuclear contributions	Environmental advocacy in favour of the commitments outlined in the Agenda 2030 and the Paris Agreement. Acting on the topic of climate change.
Revolusolar	3rd Sector	Low-income communities in Rio de Janeiro	The change in the rules jeopardizes the legal certainty and regulatory predictability of the DG segment	Maintenance of rules for greater legal certainty in solar investments.
MSL	3rd Sector	Energy consumers, entrepreneurs, workers, academia	Changing the established rules is not consistent with the policy of universal access to energy in the country	Expansion of the solar source in the electric sector

Source: Own authorship, 2022.

For this group, the solar source has the potential to promote social development, considering the creation of jobs, private capital investment, and the savings generated for the government spending. Also, it can promote an energy transition towards a cleaner and more sustainable electricity matrix, reducing greenhouse gas (GHG) emissions and contributing to the achievement of international commitments and goals. In addition, Group 1 believes that the incentive to this source generates

economic, social, and environmental benefits, besides reducing the pressures on the distribution and transmission grids and encouraging local energy consumption.

In turn, Group 2 is composed of Aneel, TCU, Congressmen Marcelo Ramos and Lafayette de Andrada (Table 2).

Table 2 | Composition, Representation, and Main Arguments of Group 2

GROUP 2 *Against the Rules established in NR no. 482/Aneel*				
Actor	*Society Sector*	*Representation*	*Main Arguments*	*Main interests*
Aneel	1st Sector	Society	The change in rules is necessary to ensure that the system continues to grow sustainably without impacting other consumers	Decrease the incentive to use DG in favour of economic benefits for the energy utilities (lobby)
TCU	1st Sector	Society	"The rules for using DG need to be built on solid foundations that do not reduce efficiency at the expense of other bases in the electricity sector, especially low-income consumers" (NETO, 2021)	Decrease the incentive to use DG in favour of economic benefits for the energy utilities (lobby)
Marcelo Ramos	1st Sector	Amazonas State	The rules established in NR No. 482 have no legal prevision and configure a "cross-subsidy", in which the "poorest" pay for the costs of the "rich	Decrease the incentive to use DG in favour of economic benefits for the energy utilities (lobby)

Source: Own authorship, 2022.

This group believes that the EECS established in NR Nº. 482 generates losses for non-DG users since it transfers costs not paid by the DG users to the "poorest" part of the population. According to this Group, this reduction in the tariff for DG users impacts the maintenance costs of the transmission networks since the tariff also remunerates these costs. That way, Group 2 is against the EECS established in NR Nº. 482.

4 DISCUSSION

Although the EECS allows the reduction and even cancellation of electricity tariffs, the generating consumers continue to pay for the availability fee, charges, and public lighting. Based on this relationship, Group 1 is in favour of maintaining the EECS, mainly because of its importance for photovoltaic energy generation in the country and for making possible even greater contributions to the Brazilian electricity matrix.

In addition to environmental benefits generated by the increased use of the solar source, Group 1 also relates the regulation and the EECS to the "more than 233,000 jobs and more than 39.8 billion in new investments" (BAITELO, 2021) in Brazil since the publication of the regulation. Also, the movement of this market can generate additional income for the population and promote a fairer and more inclusive economy (KALOGIROU, 2004; MARTINS, 2017; VIEIRA, 2016).

This Group recognizes the importance of the EECS and a regulatory framework for the sector. Moreover, this instrument's absence is considered to be the main barrier to advancing the solar source in Brazil. Therefore, countries such as Germany, Italy, Japan, Spain, and the United States, for example, have invested in public policies and incentive programs to expand the use of photovoltaic systems, with a primary focus on electrical decentralization (MACHADO; MIRANDA, 2015).

Germany, for example, implemented its most high-profile policy in 1998 to install 1,000 photovoltaic systems in the country (PUIG; JOFRA, 2007). In California, the government makes it mandatory to use photovoltaic systems in new constructions (RHODES, 2020; WEDY, 2021). The literature shows that leading countries in installed solar capacity have been investing in plans for solar source expansion for at least 20 years (PUIG; JOFRA, 2007; SHARMA; TIWARI; SOOD, 2012; WEDY, 2021).

Furthermore, other actors in this Group also report the benefits of the solar source for the stability of the Brazilian electricity system. One example is to take advantage of the source for more massive electrical support and rely on the hydroelectric plants for supply during the "absences" of the solar source and other renewables (SILVA, 2021). Since "these sources, however intermittent, contribute to the security, stability, and reliability of the Brazilian electricity system" (SILVA, 2021).

On the other hand, Aneel and the TCU (Group 2) did not consider the arguments presented above at the time of the analyses to revise the regulation. The two bodies claimed that they are responsible for regulating the sector and auditing the Federal Administration's accounts and that socioeconomic and environmental benefits should be an exclusive matter for the National Congress. Even though these agencies have society as the final beneficiary, the advancement of the solar source, mainly through DG, brings benefits to the National Interconnected System (Sistema Interligado Nacional – SIN) – also regulated and inspected by Aneel.

According to the results of the studies presented by the TCU, the EECS provides a subsidy to the DG user because, theoretically, this user does not pay for the excess energy produced injected back into the grid. Besides having the monthly electrical tariff practically zeroed, which in theory, stops remunerating the electric power utilities. With this, the TCU presented concerns about the expenses until 2035 with the continuity of this subsidy.

However, the estimate of these expenses is not expected to come from the public coffers but rather from the energy utilities, which theoretically would no longer receive this revenue. In addition, the Court's opinion on the regulation seems to be concerned with the regulation of private market issues, which should not be the Court's study object.

Corroborating this study, Deputy Marcelo Ramos understands that the absence of remuneration for the utilities generates more expenses for maintaining the distribution networks. In this case, these costs are transferred to the tariffs of traditional consumers who are not DG users. Eid's (2014) study also supports this argument, which presents the possible consequences of deploying net-metering systems[1] from solar energy. Despite recognizing its importance in reducing GHG emissions and mitigating the effects of climate change.

However, Brown (2017) points out that even though the costs of net metering are passed on to the utilities, this "loss" is offset by the benefits that solar energy brings to them, such as the reductions in spending on generation, transmission, distribution, and management of their own networks. In addition to reducing negative externalities to the environment and consequently to society and replacing centralized power generation systems (BROWN, 2017).

Based on these arguments, Group 2 believes that the EECS is a cross-subsidy mechanism in which non-DG users pay for the tariffs of DG users. Based on this, Marcelo Ramos classifies NR Nº. 482 as a "Robin Hood policy in reverse", where the "poor" pay part of the bill for the "rich".

Group 1 sees just the opposite of this relationship: DG's benefits would not only be for the generators and users themselves but for society, especially for the Brazilian electrical system. With the decrease of captive consumers in conventional networks, there is also a decrease in the need for maintenance and new investments in transmission and distribution networks, transforming electrical consumption into something more local and decentralized, in addition to the injection of surplus energy directly to the grid (BROWN, 2017).

In addition, using the solar source enables new planning and "optimization of new investments in generation, transmission and distribution of energy" (MARTINS, 2017, p. 12).

Therefore, for Group 1, the growing installation of photovoltaic systems is increasingly interesting for the energy (and environmental) security of Brazil and the autonomy of its consumers, generating positive effects for the grid and mainly for society (BROWN, 2017). On the other hand, Group 2 sees this increase in installations as a "vicious circle" for the utilities' profits.

From this discussion, the idea of "taxing" the surplus production that is not consumed and injected into the network was born. Group 1 saw this possibility as an obstacle and a disincentive to the DG user, claiming that the proposal did not match the reality and irradiation potential of the country. Besides being a step backwards for environmental issues, especially in the context of climate change, which makes electrical systems even more vulnerable. The position of these actors is that the government should further encourage the uptake of solar energy by presenting incentives and new proposals to make its supply system more reliable and stable. Besides considering the importance of the solar source for the energy demand in the country and the world matrix (KABIR, 2018).

They even present comparative studies of subsidies applied to society by the government to increase the use of solar power, as in California. There, "the government subsidizes about 80% of the costs, provides legal certainty for 20 years for the EECS, and presents other even more impressive legislation" (PINTO, 2021).

In countries like Germany, for example, the government considers distributed generation from renewable sources more expensive than that provided by the grid. Moreover, it remunerates the producer for the surplus generated through the premium tariff system – feed-in-tariff (FIT) (MACHADO; MIRANDA, 2015). The same instrument is used in Australia, although with an added incentive, since the Australian premium tariff considers the total gross generation for producer remuneration for 20 years from the date of implementation of the policy (LAMARCA JÚNIOR, 2012).

In the United States, though, the government proposes an individual or corporate income tax reduction of up to 30% for users of distributed generation with photovoltaic systems – Instrument Investment Tax Credit (ITC) (CALAZANS, 2016; WEDY, 2021), in addition to the Modified Accelerated Cost Recovery System (MACRS) which provides for the recovery of investments in photovoltaic systems through annual deductions (CALAZANS, 2016; WEDY, 2021).

Other incentives are applied to other countries to encourage solar energy, such as investment tax credits; public financing and investment programs; and direct capital subsidies (TIMILSINA; KURDGELASHVILI; NARBEL, 2011; LAMARCA JUNIOR, 2012). In addition, there is the net metering system in which excess production from the system is sold to power companies to be made available to other consumers (JEAN *et al.*, 2021; LAMARCA JÚNIOR, 2012; TIMILSINA; KURDGELASHVILI; NARBEL, 2011). Furthermore, renewable energy portfolio standards set targets for the share of renewable sources for energy suppliers (LAMARCA JÚNIOR, 2012; TIMILSINA; KURDGELASHVILI; NARBEL, 2011).

The literature shows that the rules established in Aneel NR Nº. 482 conform, even if only in a preliminary way, with the main policies adopted around the world in relation to the promotion of solar energy and

DG. Several countries adopt combinations of these instruments to enhance their results in terms of installed capacity.

Considering all these aspects, Bill of Law 5829, 2019, was presented to establish legal certainty for the sector and present fewer rigid proposals for the EECS than Aneel. The public debate, with its various slogans and arguments, lasted two years and created a tax on the surplus electricity generated.

Given the approval of the regulatory framework, Group 1 was satisfied with the final draft proposal, which contains fairer and more feasible rules for the sector. Although costs for DG consumers have increased, new consumers do not find the EECS the most advantageous way.

Group 2, on the other hand, had reservations about maintaining the EECS and was dissatisfied with the final wording of the Bill. These actors understood that the Bill still leaves the utilities at a disadvantage and classified it as not ideal but fairer than NR Nº. 482.

On the other hand, the framework is not in dialogue with the country's sustainability agenda – mainly with the 2030 Agenda and the Paris Agreement –and was not designed in an integrated manner with other sectors of society that also influence the sector.

The 2030 Agenda for sustainable development is composed of 17 Sustainable Development Goals (SDGs) and 169 integrated targets, which consider the different realities and development and policy capacities of the agreeing countries (MCCOLLUM, 2018; PEIXER, 2019; VASCONCELOS; DE MORAES MELLO, 2021). The emergence of the Agenda is precisely to achieve a world with a safe and secure environment and universal access to energy sustainably and reliably (UN, 2015).

Against this background, the discussion of the regulatory framework could have also contemplated the new challenges of national and international cooperation in the search for innovative and integrated solutions (MCCOLLUM, 2018; PEIXER, 2019; UN, 2015). Since the 2030 Agenda presupposes a global engagement that includes local and federal governments, civil society, universities and education and research centres, the private sector, and all the actors necessary for the implementation of these integrated, complex, and innovative goals (PEIXER, 2019; UN, 2015).

The centrality of SDG 7 to the Agenda makes it clear how much this theme demands joint and broad efforts from all sectors of society. Access to energy correlates with the creation of new jobs, the opening of new technological markets, and innovation possibilities (AKTER *et al.*, 2017; BERNARD; TORERO, 2015; BURNEY *et al.*, 2017; CHAKRAVORTY *et al.*, 2014; GROGAN; SADANAND, 2013; MCCOLLUM, 2018; PUEYO *et al.*, 2013; RAO; 2013; VAN VUUREN *et al.*, 2015), and "fostering a Country's economic growth" (SCHWERHOFF, 2017, p. 3).

Similarly, energy access and use of renewable sources is also a central theme for reducing global GHG emissions (ANENBERG *et al.*, 2013; CHERIAN, 2015; GAMBHIR *et al.*, 2017; KRIEGLER *et al.*, 2013; KRIEGLER *et al.*, 2014; MCCOLLUM, 2018; RIAHI *et al.*, 2015; RIAHI *et al.*, 2017; ROGELJ *et al.*, 2013; VAN VUUREN *et al.*, 2015). This contribution is directly linked to the Contributions outlined by Brazil in the Paris agreement.

The Paris agreement, ratified and in force since November 2016, is considered the world's largest pro-climate agreement (FALKNER, 2016; LACLIMA; OBSERVATÓRIO DO CLIMA, 2021; SOUZA; CORAZZA, 2017). It aims to stabilize global temperature below 2°C while maintaining efforts to limit it to 1.5°C (FALKNER, 2016; LA CLIMA; OBSERVATÓRIO DO CLIMA, 2021; PEIXER, 2019; SECAF, 2016; SOUZA; CORAZZA, 2017). To this end, countries have committed to present long-term strategies for reducing GHG emissions, called Nationally Determined Contributions (NDCs) (FALKNER, 2016; REI; GONÇALVES; DE SOUZA, 2017; SOUZA; CORAZZA, 2017). The Brazilian NDC commits to reducing GHG emissions

by 37% by 2025 and by 43% by the year 2030, considering the entire Brazilian territory and economy (BRASIL, 2015; PEIXER, 2019; REI; GONÇALVES; DE SOUZA, 2017).

Considering that the energy sector is the largest emitter of GHG in Brazil (responsible for 33% of emissions) (MENDES, 2020) and that the commitments made will require even greater efforts in the sector, in public policies and in the planning done by the government, the discussion about Law Nº. 14300/2022 could have been used to plan these actions. They are mainly linked to the expansion possibility of the solar source and incentives to the use of new renewable sources so that these have more and more competitiveness and market dominance. The largest electric participation today is related to the hydroelectric source, which makes the energy matrix clean, but centralized and not very diverse.

5 CONCLUSIONS

Despite the socioeconomic and environmental benefits, distributed solar power generation still faces resistance to reaching its full potential in Brazil. This happens despite the commitments established by the 2030 Agenda and by the NDCs, which point out decarbonization strategies for the world's electricity matrix through guidelines defined by each country. Based on these agreements, Brazil has made commitments to reduce GHG emissions. However, it has not established any action plan for this goal, whether considering the expansion of new renewable sources or new generation forms, such as decentralized generation.

On the other hand, starting with the establishment of Aneel Resolution Nº. 482/2012, distributed generation skyrocketed in Brazil and was responsible for the increase in installed capacity at record levels of the solar source in the country. Nevertheless, the debates about the revision of NR Nº. 482 have not considered the strategic nature of the theme, the opportunity costs and the savings to the public coffers due to the adoption of new sources in the electric matrix. They also disregarded international commitments, the climate and the sustainable development agenda. The active groups have been reduced in monetary discussions. With this, the disputes over the legal framework for the regulation of the sector have resulted in a setback to the incentives for its expansion.

The debates until then did not consider the strategic nature of the energy issue for social development, as well as for the 2030 Agenda established worldwide. In addition, they did not consider the real need for government investments and integrated planning to expand non-GHG-emitting sources, such as solar power.

Given this context, Brazil does not propose any integrated action plan between the different governmental or transition agendas for low-carbon economies and the transformation of sustainable cities in the 2030-2050 horizon. Therefore, the centrality of the energy issue in achieving the commitments of the 2030 Agenda and the Paris Agreement is disregarded.

NOTE

1 | Policy that allows the compensation of part or all of self-generated electricity. The system has a meter that can identify when a self-generating consumer consumes more or less energy than it produces. When there is less consumption compared to production, producers receive benefits that function as energy credits (POULLIKKAS; KOURTIS; HADJIPASCHALIS, 2013).

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Disputas e narrativas sobre o marco da geração distribuída no Brasil: retrocessos para a Agenda 2030 e o Acordo de Paris

Disputes and narratives on the distributed generation of electricity in Brazil: setbacks for the 2030 Agenda for sustainable development and the Paris Agreement

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ARTICLE- VARIA

RESUMO

A centralização e a baixa diversificação da matriz elétrica brasileira aumentaram a sensação de insegurança energética no país, um problema que ganha proporções ainda maiores diante das mudanças globais do clima. Esta pesquisa analisou a arena política em torno da regulamentação da geração distribuída de energia elétrica a fim de elucidar os entraves à sua expansão. Para tanto, foram analisados documentos, discursos, entrevistas, apresentações, material audiovisual e publicações na imprensa sobre a geração distribuída e a fonte solar no país. Os resultados da pesquisa indicaram que, apesar do grande potencial de desenvolvimento da fonte no país e dos compromissos internacionais firmados, as coalizões identificadas disputam narrativas que resultam em retrocessos para as agendas do clima e do desenvolvimento sustentável.

Palavras-chave: Aneel. Fonte Solar. Descentralização. Agendas da sustentabilidade.

ABSTRACT

Centralization and low diversification of the Brazilian electricity matrix have increased the feeling of energy insecurity. In the face of climate change, this problem is gaining greater proportions. The present research analyzed the political arena around the regulation of distributed electricity generation to clarify expansion obstacles. To this end, documents, speeches, interviews, presentations, audiovisual material, and press publications about the country's distributed generation and solar power were analyzed. Results indicated that, despite the great development potential of the source in the country and the international commitments signed, the identified coalitions dispute narratives that result in setbacks for climate and sustainable development agendas.

Keywords: Aneel. Solar energy. Decentralization. Sustainability Agendas.

1 INTRODUÇÃO

A energia solar é uma fonte inesgotável de recurso, que apresenta um grande potencial elétrico no Brasil, país detentor de níveis extraordinários de irradiação solar, mesmo em locais menos ensolarados (JEAN *et al*., 2021; PEREIRA, 2017). Embora a instalação dos sistemas fotovoltaicos tenha representado um aumento de 33% em relação aos anos de 2019 e 2020, as políticas públicas e as normativas sobre a utilização da fonte solar ainda não foram capazes de alcançar o potencial de geração brasileiro. Esse descompasso vem sendo discutido a partir da Resolução Normativa (RN) de nº 482/2012, da Agência Nacional de Energia Elétrica (Aneel).

A partir da RN nº 482, o consumidor foi autorizado e incentivado a gerar sua própria energia, por meio da instalação de sistemas fotovoltaicos. Com a resolução, o excedente da produção retornava para a rede de distribuição pública, convertido e compensado em créditos na conta de luz desse consumidor. Esse excedente era injetado e armazenado de volta à rede para o uso de outros consumidores próximos, funcionando como uma bateria para esses sistemas. Cada 1 kW/h produzido pelo sistema do consumidor era compensado por 1kW/h da rede distribuidora.

As regras estabelecidas na RN nº 482 sofreram duas revisões até o ano de 2017. A primeira objetivou a readequação e atualização das capacidades elétricas fornecidas pela Geração Distribuída (GD) no país, resultando na RN nº 687/2015. Já a segunda revisão, em 2017, deu origem à RN nº 786, que atualizou as definições de minigeração distribuída e de enquadramento à microgeração ou minigeração distribuída. A terceira revisão iniciou em 2018 (RUBIM, 2021) e teve seu processo marcado por discussões polarizadas entre os defensores do avanço da energia solar no Brasil e os opositores aos incentivos gerados pelo Sistema de Compensação de Energia Elétrica (SCEE) instituído pela respectiva normativa (Figura 1).

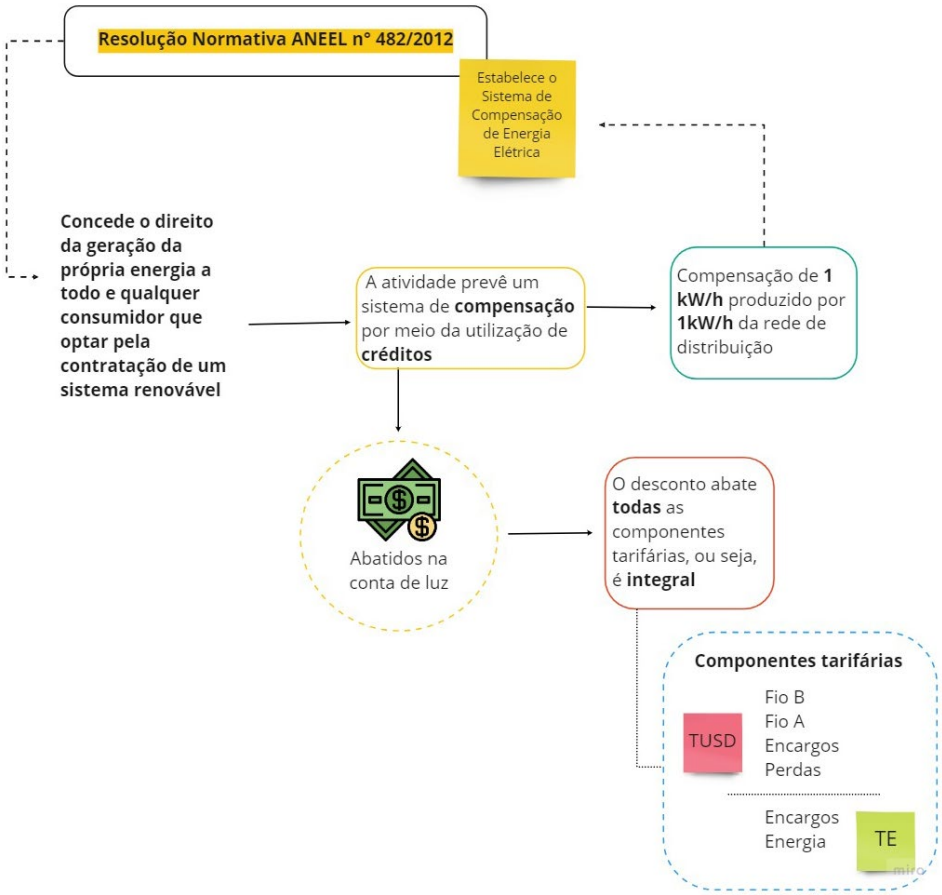

Figura 1 | Esquema resumo da principal regra estabelecida pela RN Aneel nº 482/2012

Fonte: Elaboração própria.

Apesar dos avanços proporcionados pela RN nº 482, a partir de 2015, emergiram questionamentos sobre a forma de compensação prevista pelo SCEE, principalmente por esse sistema não considerar os custos do "uso" da rede das concessionárias. A partir disso, a Aneel elaborou seis propostas para a revisão da normativa, apresentando retrocessos em relação à RN. Diante disso, o setor elétrico e a sociedade civil se mobilizaram em torno dos benefícios sociais e ambientais que a expansão do setor oferece à sociedade. O debate foi para o Congresso Nacional, na forma do Projeto de Lei (PL) nº 5.829.

Em janeiro de 2022, a matéria foi discutida de forma definitiva, dando origem ao marco regulatório da geração distribuída. A Lei 14.300/2022 instituiu um sistema de compensação parcial, no qual o consumidor pagará pelo excedente injetado na rede. No entanto, a Lei permite que todos os sistemas fotovoltaicos instalados antes de janeiro de 2023 usufruam das regras antigas do SCEE, até o ano de 2045.

Com base nisso, o objetivo deste trabalho é descrever a arena política, as narrativas e disputas que influenciaram o marco regulatório da geração distribuída no Brasil e sua interação com a Agenda 2030 e o Acordo de Paris.

2 METODOLOGIA

A análise de dados deste trabalho foi baseada em duas etapas: i) coleta de materiais escritos e de audiovisual sobre o tema de energia solar no Brasil; ii) caracterização, posicionamento, classificação e divisão dos atores com base em suas principais pautas e argumentos.

A coleta de materiais buscou entender o contexto das discussões acerca do tema e subsidiar a identificação dos principais argumentos e grupos atuantes na matéria. Os mais de 80 materiais coletados na *internet* continham posicionamentos e declarações acerca da GD e da fonte solar, entre os anos de 2018 (Terceira revisão da RN nº 482) a 2022 (Marco regulatório da GD no Brasil – Lei 14.300). Esses materiais foram integralmente transcritos para identificação, classificação e análise neste trabalho.

A partir dos materiais coletados foi possível identificar o posicionamento e os argumentos apresentados por cada um dos atores que aparecem nos materiais. Ao longo da análise, 80 atores foram identificados, e com base no critério de maior Frequência Absoluta (FA) de citações nos materiais coletados, sete foram priorizados para análise neste estudo, a saber: i) Aneel; ii) Ministério Público (MP); iii) Associação Brasileira de Energia Solar Fotovoltaica (Absolar); iv) Tribunal de Contas da União (TCU); v) Sociedade Civil – Associação Movimento Solar Livre (MSL), Instituto Nacional de Energia Limpa e Sustentável (Inel), Observatório do Clima (OC) e Revolusolar; vi) Câmara dos Deputados – Deputados Beto Pereira, Rodrigo Agostinho, Lafayette de Andrada e Marcelo Ramos; e vii) o chefe do Executivo, Jair Messias Bolsonaro.

Com base na leitura dos materiais analisados, dois principais grupos foram identificados: i) a favor das regras da RN nº 482; ou ii) contra as regras da RN nº 482. A partir disso, esses atores foram descritos em seus respectivos grupos e principais argumentos.

3 RESULTADOS

3.1 CARACTERIZAÇÃO, POSICIONAMENTO, CLASSIFICAÇÃO E DIVISÃO DOS ATORES

3.1.1 AGÊNCIA NACIONAL DE ENERGIA ELÉTRICA (ANEEL)

A Aneel é uma autarquia de regime especial, vinculada ao Ministério de Minas e Energia (MME), que objetiva a regulação do setor elétrico brasileiro (ANEEL, 2022), incluindo as modalidades de GD e Microgeração Distribuída.

A Aneel estabeleceu as condições gerais para a geração distribuída, em 2012, com a RN nº 482. Essa norma permitiu a conexão de um sistema de geração próprio, de fontes renováveis, às redes de distribuição das concessionárias. Esse processo marcou o avanço da energia solar no Brasil. Em 2015, a Agência revisou a normativa e aplicou novas regras que impulsionaram ainda mais o uso da fonte solar no país, dando origem à RN nº 687/2015.

No entanto, apesar de a atualização funcionar como uma política de incentivo à energia solar no Brasil, a própria Resolução já previa a revisão dessas regras. Por isso, em 2018 a Aneel iniciou o terceiro ciclo de revisão das normativas de nº 482 e de nº 687, com o objetivo de reavaliar as regras estabelecidas.

A partir desses debates, a Aneel elaborou seis propostas para alteração à RN nº 482 e, a partir disso, abriu uma Consulta Pública (CP) de nº 10/2018 para discutir as propostas apresentadas. O debate gerou uma Avaliação de Impacto Regulatório (AIR) – nº 04/2018 –, que culminou em diversas audiências públicas, recomendações e estudos acerca do SCEE.

Em 2019, a Aneel abriu nova CP – nº 025/2019 –, com redação preliminar para a Resolução. A redação seguia a proposta de nº 6 – a opção mais rígida para o SCEE – e se diferia das principais discussões e recomendações da CP anterior. Nessa proposta, o SCEE compensaria 1 kW/h produzido pelo consumidor por 0,3 kW/h injetado na rede distribuidora.

A CP e a proposta apresentada não foram aceitas pelos atores do setor e pela sociedade civil. Por sua vez, a Aneel não legitimou os argumentos apresentados e se posicionou contra a manutenção do atual SCEE estabelecido por sua própria normativa de nº 482, de 2012.

3.1.2 MINISTÉRIO PÚBLICO (MP)

O MP possui atuação independente e autônoma, assegurada pela Constituição Federal, em matérias de interesse público.

Em outubro de 2019, o MP interveio no processo de revisão da Aneel com a instauração de um Procedimento Administrativo (PA). O PA pretendeu “acompanhar e examinar a regularidade [...] da Consulta Pública nº 025/2019, que objetiva revisar a Resolução n° 482” (MPF, 2019). A partir disso, o MP solicitou esclarecimentos sobre a revisão ao MME e à Aneel. De forma complementar, requisitou à Absolar um estudo sobre os prejuízos gerados para a sociedade, a partir das alterações propostas pela Aneel (MPF, 2019).

Em novembro de 2019, o MP emitiu sete recomendações oficiais à Aneel. No documento, o MP enfatizou o dever e a responsabilidade da administração pública ante a situações de abuso de poder regulatório, que possam favorecer grupos econômicos, aumentos de custos sem comprovações de benefícios diretos e interfiram na chegada de novos competidores aos mercados.

O MP julgou as normas estabelecidas pela RN nº 482/2012, como "um marco regulamentar pioneiro e fundamental para o desenvolvimento do setor de microgeração e minigeração distribuída de energia elétrica" (MPF, 2019), sendo indutora de uma indústria que é geradora de empregos, de desenvolvimento, e de independência do fornecimento de energia elétrica.

Sobre o SCEE estabelecido pela RN nº 482, o MP ponderou que a regra possibilita a geração de energia elétrica sem necessidade de investimento de capital público, além de ser capaz de "pulverizar no território nacional, a geração de energia elétrica distribuída, limpa, inesgotável e ambientalmente correta" (MPF, 2019). Ainda segundo o MP, "o sistema possui um valor inestimável por fomentar uma atividade que visa a independência da sociedade civil, mesmo que parcial, em relação aos serviços públicos" (MPF, 2019).

O MP também reconhece que a fonte solar é:

> "uma fonte totalmente renovável, inesgotável e alternativa para os desafios da expansão da oferta de energia. Principalmente em relação aos baixos impactos ambientais e aos desejos de diversificação da matriz elétrica brasileira" (MPF, 2019).

Além de reconhecer também os benefícios da geração distribuída, que contam com a produção de energia próxima ao consumo, redução do uso de termelétricas e das linhas de transmissão, diminuição da pressão das redes de distribuição, e "minimiza os investimentos em geração, transmissão e distribuição de energia elétrica, além da redução das perdas" (MPF, 2019), problema que afeta todos os usuários do sistema elétrico brasileiro.

Por fim, o MP entendeu que a nova proposta geraria insegurança jurídica para os investidores e consumidores, e prejuízos individuais e coletivos. Ademais, o MP também alegou que a nova proposta da Aneel é divergente da Política Energética Nacional – Lei nº 9.478, de 1997 – do Brasil.

O MP se posicionou a favor da manutenção das regras estabelecidas na RN nº 482/2012, por reconhecer os avanços sociais, econômicos e ambientais que esse tipo de geração promove.

3.1.3 ASSOCIAÇÃO BRASILEIRA DE ENERGIA SOLAR FOTOVOLTAICA (ABSOLAR)

A Absolar foi protagonista nas discussões sobre o tema, representada pelas figuras de Bárbara Rubim – vice-presidente de Geração Distribuída – e de Rodrigo Lopes Sauaia – presidente-executivo. A participação da Absolar trouxe recomendações para a Aneel com análises técnicas, econômicas, sociais e ambientais sobre as contribuições da energia solar à sociedade (SAUAIA, 2021).

Segundo a Absolar, o setor fotovoltaico gerou mais de 233 mil empregos aos brasileiros, e movimentou mais de 39,8 bilhões de reais em novos investimentos, desde 2012. Em termos públicos, o setor arrecadou mais de 11,6 bilhões de reais em tributos e evitou a emissão de mais de 1,1 milhão de toneladas de gás carbônico (BAITELO, 2021).

Diante disso, a Aneel se recusou a apreciar os argumentos apresentados por não considerar o tema de competência regulatória do órgão. A partir disso, a Absolar e outros interessados se mobilizaram para que a RN nº 482 se tornasse um PL no Congresso Nacional. A proposta buscava uma alteração mais branda do que a apresentada pela Aneel.

Desde o início dos debates, a Absolar também se posicionou a favor da instituição de um marco regulatório para o setor, que gerasse mais segurança jurídica para seu desenvolvimento. Segundo Rodrigo Sauaia:

> A energia solar é uma tecnologia [...] geradora de empregos e desenvolvedora de novos projetos, que atraem novos investimentos e que não dependem de investimentos do setor público. A GD, por exemplo, é uma decisão do consumidor, é o próprio consumidor que investe na energia solar e assume esse investimento, irrigando a economia do país e a sua própria economia no quesito energia elétrica. E a economia desse recurso [...] vai ser utilizada na aplicação de outros consumos, como, por exemplo, a alimentação, saúde, educação, que se injetam na recuperação econômica do país (SAUAIA, 2021).

A Absolar se posicionou a favor da manutenção das regras estabelecidas na RN nº 482/2012.

3.1.4 TRIBUNAL DE CONTAS DA UNIÃO (TCU)

O TCU "é um órgão de controle externo do governo federal, que acompanha a execução orçamentária e financeira do país" (TCU, 2022).

O TCU ingressa no debate sobre a RN n° 482 a partir do pedido de esclarecimento do MP sobre possível violação da Aneel à segurança jurídica e boa-fé de consulta pública instaurada em 2019.

A representação do MP solicitou que a Aneel congelasse o processo de consulta pública até que o órgão fosse capaz de julgar a matéria. Na ocasião, o TCU entendeu que não havia mérito para a concessão cautelar, entretanto, vislumbrou o pedido como uma oportunidade para "exercer o controle sobre tema sensível ao setor elétrico".

Com base nos estudos apresentados pelas partes solicitadas, o TCU julgou improcedente a representação do MP, e julgou a CP em questão como "regular e de acordo com os princípios da legalidade, legitimidade, razoabilidade, segurança jurídica e da boa-fé" (TCU, 2020).

O órgão reconheceu a importância do SCEE contido na RN nº 482/2012 para o avanço da mini e microgeração distribuída no Brasil, entretanto, identifica:

> uma política de subsídio cruzado entre os consumidores de energia elétrica, de natureza regressiva em termos de distribuição de renda, que tem pressionado a tarifa dos consumidores de menor poder aquisitivo e tornado menos onerosos os gastos dos consumidores com maior renda (TCU, 2020).

Além do argumento sobre os gastos com o SCEE, o TCU também levantou a hipótese de que a RN nº 482/2012 descumpre a Lei Geral das Concessões, por autorizar a diferenciação tarifária para consumidores de energia elétrica que possuem GD e para aqueles que não possuem. O órgão alega tratamento discriminatório aos consumidores, e instrumento ilegal de regulação. Relata também que o sistema vigente "gera externalidade negativa aos demais consumidores e às concessionárias de energia elétrica" (TCU, 2020), que, por sua vez, geram ineficiências econômicas e vão contra os preceitos de justiça social. Segundo o relatório, esses fatores se tornam um "espiral da morte" para as distribuidoras de energia, pois comprometem a arrecadação futura de receitas das distribuidoras (TCU, 2020).

O relatório também solicitou que as informações do processo fossem compartilhadas com a Câmara dos Deputados, Senado Federal e outras autoridades que estivessem envolvidas na discussão dos projetos de lei que tramitam no Congresso Nacional.

O órgão considerou improcedente as representações apresentadas e determinou a retirada da diferenciação tarifária presente na RN nº 482/2012. Visto isso, o órgão se posicionou contrário à manutenção do atual sistema de compensação elétrico estabelecido pela RN nº 482.

3.1.5 OBSERVATÓRIO DO CLIMA (OC)

O OC é uma coalizão de grandes organizações da sociedade civil, criada em 2002, para discussão sobre os efeitos das mudanças climáticas.

O Observatório também se engajou no debate em busca da manutenção das regras contidas na RN nº 482, frisando também a importância do engajamento da sociedade e das organizações em prol do avanço da energia solar, como destacado no trecho a seguir:

> [...] a população, a opinião pública, têm que estar muito mobilizadas para exigir do governo que o Brasil realize os seus potenciais energéticos e climáticos e que seja um exemplo pro mundo. Que também faria muito bem para a nossa economia e para cada um de nós brasileiros" (ASTRINI, 2022).

Segundo o OC, o Brasil se destaca pela capacidade de geração de energia solar, justamente por apresentar um grande potencial devido ao alto nível de irradiação que o país recebe o ano inteiro (ASTRINI, 2022). Apesar disso, Márcio Astrini, secretário-executivo do OC, afirma que faltam investimentos e políticas públicas para o tema (ASTRINI, 2022).

3.1.6 INSTITUTO NACIONAL DE ENERGIA LIMPA (INEL)

O Inel "é um centro de inteligência para apoiar os esforços em prol das fontes de energia limpa e sustentável" (INEL, 2022). E tem como objetivo a "promoção da democratização do acesso à energia limpa e mais barata a toda a sociedade" (INEL, 2022).

De acordo com Rodrigo Pinto, consultor do Inel, caso a atualização da normativa fosse concretizada, os investimentos solares no Brasil se tornariam inviáveis economicamente e inseguros em termos jurídicos. Segundo Rodrigo, "é vergonhoso para o Brasil, a contribuição da solar hoje, em relação à contribuição de outras fontes mais caras, como a nuclear e a fóssil" (PINTO, 2021).

Já em relação ao SCEE, o consultor do Inel esclarece que "uma política pública inteligente, seria uma política pública que incentive o produtor de GD a inserir sua energia na rede de distribuição local" (PINTO, 2021), visto seus diversos benefícios econômicos, tanto em termos de produção, distribuição e perdas de energia elétrica. Para Rodrigo, a revisão da normativa e a aprovação da proposta de n° 6 da Aneel "tomam um caminho contrário a uma política pública inteligente, pois realmente tenta limitar o brasileiro a investir em painéis solares" (PINTO, 2021).

3.1.7 MOVIMENTO SOLAR LIVRE (MSL)

O MSL é uma associação que representa diversas empresas do setor, coletivos docentes e discentes, e a própria sociedade. Tem como principal objetivo a "democratização da energia limpa e renovável no Brasil, e do livre acesso à energia solar" (MSL, 2022).

O MSL se engajou no tema buscando a divulgação das propostas de revisão e ampliação da participação da sociedade nas discussões sobre o tema. O Movimento se declarou contra a proposta de nº 6 da Aneel, sendo traduzida como contra a "taxação" do sol. A partir do engajamento social promovido, a expressão "taxar o sol" se tornou o grande *slogan* da corrente contrária à revisão da Aneel.

De acordo com o MSL, "taxar o sol" "é um absurdo, pois a energia solar tem tão baixa penetração no Brasil" (ALOÍSIO NETO, 2021) e não é justificável, principalmente frente a uma lei de universalização do acesso à energia.

3.1.8 FUNDAÇÃO REVOLUSOLAR

A Fundação Revolusolar é "uma associação sem fins lucrativos [...] que tem o propósito de promover o desenvolvimento sustentável de comunidades de baixa renda através da energia solar" (REVOLUSOLAR, 2022).

A Revolusolar classificou a proposta apresentada pela Aneel como: "absurda, que taxa em cerca de 60%, passa por cima das contribuições do setor e põe em risco a segurança jurídica e a previsibilidade regulatória daqueles que investiram no segmento da GD desde 2012" (REVOLUSOLAR, 2021). Além disso, a Fundação também expõe desconforto acerca dos investimentos e subsídios aplicados aos combustíveis fósseis e "grandes usinas nocivas para o meio ambiente e para as comunidades" (REVOLUSOLAR, 2021).

Diante das implicações que a alteração da RN nº 482 poderia gerar no setor, a Fundação se engajou no movimento "#TaxarOSolNão" e se destacou perante a sociedade civil como agente atuante.

3.1.9 CÂMARA DOS DEPUTADOS

A Câmara dos Deputados recebeu os pedidos protocolados de Projetos de Lei (PL) para a transformação da RN nº 482 em lei específica, e durante os debates recebeu mais de 100 propostas de redação, emendas parlamentares e outros documentos referentes à matéria. Os diversos protocolos apresentavam propostas para a oficialização do SCEE como estabelecido pela RN nº 482 e, também, para a instituição de formas de cobrança mais rígidas para usuários de geração distribuída.

Nesse debate, de quase quatro anos, os deputados Silas Câmara, Marcelo Ramos, Lafayette de Andrada, Beto Pereira e Rodrigo Agostinho tiveram maior destaque nas discussões.

O deputado Silas Câmara, filiado ao partido Republicanos pelo estado do Amazonas, foi o autor do PL 5.829/2019. A proposta inicial buscava "Instituir o marco legal da microgeração e minigeração distribuída, o SCEE e o Programa de Energia Renovável Social (Pers)" (BRASIL, 2019). Segundo Silas, o PL tem potencial de "economizar mais 300 bilhões de reais em termos de investimento [...] e gerar mais de um milhão de empregos no Brasil" (CÂMARA, 2021). Além disso, o deputado acredita no poder de investimento que o marco regulatório pode trazer aos empresários, tanto em termos de fabricação de placas solares como em relação à geração de novos empregos.

As tratativas no Congresso sobre o PL 5.829 começaram a se tornar mais frequentes a partir dos avanços das discussões. Logo, em 2021, o deputado Lafayette de Andrada foi nomeado relator do Projeto. Desde então, o deputado buscou conciliar as principais propostas apresentadas à casa, buscando acordos com os dois "lados" do debate. Ao longo dos anos de discussão, Lafayette abriu diálogos para a manutenção das regras atuais do SCEE para os usuários antigos e ao mesmo tempo para a diminuição da proporção de compensação para os novos usuários.

Já Marcelo Ramos, deputado federal do estado do Amazonas, durante a tramitação do PL 5.829/2019 filiado ao Partido Liberal (PL), foi contra a manutenção das regras de compensação estabelecidas pela RN nº 482, durante todos os anos de discussão sobre a matéria. Devido à sua forte atuação nas discussões, tornou-se o principal representante contrário aos incentivos à geração distribuída do Poder Legislativo.

O deputado alega que não há previsão legal para o SCEE estabelecido pela RN nº 482, e que esse sistema se configura como um "subsídio" a esses autogeradores, igualmente sem amparo legal para que ocorra. Esses argumentos se amparam nas conclusões apresentadas pelo TCU.

Segundo o entendimento do deputado, o então "subsídio" estabelecido pela Aneel é prejudicial aos consumidores elétricos que não possuem geração distribuída, pois faz com que esses consumidores

paguem pelas tarifas dos usuários de GD. Em seus diversos pronunciamentos, Marcelo Ramos também expõe sua opinião sobre a "taxação" do sol, expressão que caracterizou o debate sobre a RN nº 482:

> [...] eu quero primeiro repor a verdade e a racionalidade desse debate. Na verdade, ninguém está discutindo taxar o sol, o que nós estamos discutindo é parar de taxar o pobre para pagar a energia do rico. O subsídio que existe hoje na GD é uma verdadeira política de Robin Hood às avessas [...], de quem não tem condições de contratar GD e colocar placa solar, de pagar parte da conta de quem tem, que são as pessoas de maior poder aquisitivo [...] (RAMOS, 2021).

Durante as tramitações na Câmara, até a concretização do marco regulatório, Marcelo Ramos se apresentou como defensor do fim do SCEE e "dos pobres" não usuários de GD:

> O grande problema é quem pode comprar uma placa de energia solar para ter geração própria. Os pobres não podem. E quando a classe média e classe alta passam para a energia solar e param de pagar a conta do fio, essa conta vai para alguém. Vai pra quem? Para o consumidor cativo, que é o pobre que não consegue pagar uma placa de energia solar (RAMOS, 2021).

Por outro lado, os deputados Beto Pereira e Rodrigo Agostinho foram defensores do SCEE estabelecido pela RN nº 482, e, para isso, apresentaram PLs específicos e emendas ao PL 5.829, além de se posicionarem publicamente em espaços de discussão e decisórios da Câmara dos Deputados. Para o deputado Beto Pereira:

> [...] a Aneel, no ano de 2019, teve a pretensão numa medida única e exclusiva, unilateral, fazer com que o setor todo fosse devastado. Aquela medida, que essa casa se rebelou, inviabilizaria qualquer tipo de investimento em energia renovável nesse país (PEREIRA, 2021).

O deputado também questionou a presença do ministro de Minas e Energia durante as plenárias realizadas sobre o assunto e nas audiências da Comissão de Defesa do Consumidor – espaço onde o tema também foi discutido. Beto Pereira destacou a importância da presença de um representante do governo federal nos debates, uma vez que a Câmara dos Deputados e a sociedade precisam saber o posicionamento do governo sobre a política energética brasileira e os planos futuros para as energias renováveis no país.

Diante de seu constante envolvimento com o tema, o deputado apresentou à Câmara o PL 2.215/2020, que tinha por objetivo alterar "a Lei nº 9.074, de 7 de julho de 1995, para estabelecer o Sistema de Compensação de Energia Elétrica (SCEE)" (BRASIL, 2020). O PL foi apensado ao PL 5.829/2019 e passou a ser discutido pelo relator Lafayette de Andrada.

Da mesma maneira, o deputado Rodrigo Agostinho participou ativamente da construção do PL 5.829/2019. Para Agostinho, o tema é de interesse nacional, e o desenvolvimento dessa política pública é fundamental para o avanço da energia limpa no Brasil. Ainda segundo o deputado, será de extrema importância que os defensores do setor se unam, pois "o pessoal não vai querer abrir mão das termoelétricas, da indústria podre do carvão. A gente vai ter que fazer um enfrentamento e ter a nossa agenda com muita união e tocar isso pra frente" (AGOSTINHO, 2020).

Nesse sentido, o deputado propôs oito Emendas Parlamentares (EMP) ao texto do projeto. Dessas oito, cinco EMP foram rejeitadas pelo relator, sob o argumento de já estarem contempladas na proposta ajustada do projeto. Destaque para a emenda 21 que propõe a diminuição do preço do pagamento pela Tarifa de Uso do Sistema de Distribuição (Tusd) fio B, considerando um prazo de escalonamento sobre o valor pago (RUBIM, 2021).

Além dessas contribuições, o PL 5.829 recebeu outras 59 propostas de EMP, entre opositores e apoiadores do SCEE. Ao final de dois anos de discussões, ajustes textuais e emendas do Senado Federal, o PL 5.829 teve sua redação final no dia 17 de dezembro de 2021. A redação final se tornou a Lei nº 14.300/2022, no dia 07 de janeiro de 2022.

A Lei nº 14.300 manteve as regras estabelecidas pela RN nº 482/2012, sobre o SCEE, para todos os consumidores já conectados à rede e para novos projetos até o mês de janeiro de 2023. Para esses consumidores, as atuais regras estarão mantidas até o ano de 2045. Já os novos consumidores, conectados à rede a partir de 2023, terão a energia gerada parcialmente compensada. Pois esses novos projetos passarão a remunerar parte do Fio B (tarifa que remunera as distribuidoras) ou parte do Fio A (tarifa que remunera as transmissoras). A novidade em relação a essas remunerações é que essas tarifas serão escalonadas ao longo de cada ano.

Apesar da votação unânime sobre a redação final do PL 5.829, os deputados Marcelo Ramos e Lafayette de Andrada entenderam que o SCEE está mais "justo" do que o previsto na RN nº 482, embora acreditem que os incentivos ao sistema deveriam ter diminuído ou até excluídos.

Da mesma forma, os defensores do SCEE entendem que a Lei é mais flexível e vantajosa para o avanço da energia solar que a proposta de revisão apresentada pela Aneel. Embora também não tenha sido a mais compatível com a atual situação energética do Brasil e com os compromissos firmados pela Agenda 2030 e o Acordo de Paris.

3.1.10 PRESIDÊNCIA DA REPÚBLICA

Diante dos debates sobre a revisão da normativa, Bolsonaro se manifestou contra a proposta de revisão da RN nº 482 apresentada pela Aneel. De acordo com o presidente, seu governo é contra a taxação da fonte solar, embora tenha ciência da autonomia da Aneel para regulação da matéria.

Em face dos desdobramentos sobre a revisão da normativa, Bolsonaro se reuniu com o presidente da Câmara dos Deputados, na ocasião Rodrigo Maia, e com o presidente do Senado, Davi Alcolumbre, para tratar da matéria. O acordo entre as partes foi o de impedir a aprovação de PLs que instituíssem a taxação da energia solar e a retirada das atuais regras do SCEE.

Decorridos quase três anos de discussões, e com a solicitação de urgência para as tratativas sobre o tema no Congresso, o Projeto de Lei 5.829/19 foi sancionado por Bolsonaro, originando a Lei 14.300/2022.

3.2 IDENTIFICAÇÃO E COMPOSIÇÃO DOS GRUPOS EXISTENTES

Os atores analisados se organizam em dois grupos: Grupo 1 – a favor das regras estabelecidas na RN nº 482/Aneel; e Grupo 2 – contrário às regras estabelecidas na RN nº 482/Aneel.

O Grupo 1 é composto por Absolar, MP, presidente da República, deputados Beto Pereira e Rodrigo Agostinho, OC, Inel, Revolusolar e MSL (Quadro 1).

Quadro 1 | Composição, Representação e Principais Argumentos do Grupo 1

GRUPO 1 *A favor das Regras estabelecidas na RN nº 482/Aneel*				
Ator	*Setor da Sociedade*	*Representação*	*Principais Argumentos*	*Principais interesses*
Absolar	3° Setor	Setor solar (empresas, fabricantes, academia, profissionais autônomos, instituições)	A manutenção das regras estimula o potencial de irradiação solar do Brasil, a diminuição de perdas elétricas, e avanços sociais	Expansão da fonte solar no setor elétrico

GRUPO 1 *A favor das Regras estabelecidas na RN nº 482/Aneel*				
Ator	*Setor da Sociedade*	*Representação*	*Principais Argumentos*	*Principais interesses*
MP	1° Setor	Sociedade	As regras estabelecidas na resolução apresentam soluções de mercado ambientalmente favoráveis	Defesa e proteção do meio ambiente e do direito adquirido do consumidor
Jair Bolsonaro	1° Setor	País	A fonte solar precisa ser estimulada pelo governo	Recorde de expansão da fonte solar durante os anos de seu governo. Intuito de ter a fonte solar como o pré-sal de seu governo.
Beto Pereira	1° Setor	Estado de Mato Grosso	Os investimentos em energias renováveis são o melhor caminho e trazem um maior equilíbrio para as questões ambientais	Manutenção das regras para maior segurança jurídica nos investimentos solares. Defesa do meio ambiente em favor dos compromissos estabelecidos na Agenda 2030 e Acordo de Paris.
Rodrigo Agostinho	1° Setor	Estado de São Paulo	A manutenção das regras amplia e favorece os investimentos em energia solar, o que diminui a dependência de combustíveis fósseis	Manutenção das regras para maior segurança jurídica nos investimentos solares. Defesa do meio ambiente em favor dos compromissos estabelecidos na Agenda 2030 e Acordo de Paris.
OC	3° Setor	Coalizão de Organizações da Sociedade Civil brasileira	A manutenção das regras estimula a capacidade brasileira de geração de energia limpa e benefícios para a economia do país	Defesa do meio ambiente em favor dos compromissos estabelecidos na Agenda 2030 e Acordo de Paris. Atuação no tema de mudanças climáticas.
Inel	3° Setor	Setor de transportes, residências, agricultura, indústrias e comércio	A contribuição da energia solar deveria ser estimulada para que fosse maior que a contribuição fóssil e nuclear	Defesa do meio ambiente em favor dos compromissos estabelecidos na Agenda 2030 e Acordo de Paris. Atuação no tema de mudanças climáticas.
Revolusolar	3° Setor	Comunidades de baixa renda do Rio de Janeiro	A alteração das regras põe em risco a segurança jurídica e previsibilidade regulatória do segmento da GD	Manutenção das regras para maior segurança jurídica nos investimentos solares
MSL	3° Setor	Consumidores de energia, empreendedores, trabalhadores e academia	Alterar as regras estabelecidas não condiz com a política de universalização do acesso à energia no país	Expansão da fonte solar no setor elétrico

Fonte: Elaboração própria, 2022.

Para esse grupo, a fonte solar tem o potencial de promover o desenvolvimento social, considerando a geração de empregos, o investimento de capital privado e as economias geradas aos cofres públicos. Além disso, é capaz de promover uma transição energética para uma matriz elétrica mais limpa e sustentável, reduzindo a emissão de Gases de Efeito Estufa (GEE) e contribuindo para o alcance dos compromissos e metas internacionais. Ademais, o Grupo 1 acredita que o incentivo a essa fonte gera benefícios econômicos, sociais e ambientais, além de reduzir as pressões nas redes de distribuição e transmissão, e incentivar o consumo local de energia.

Por sua vez, o Grupo 2 é composto por Aneel, TCU, deputados Marcelo Ramos e Lafayette de Andrada (Quadro 2).

Quadro 2 | Composição, Representação e Principais Argumentos do Grupo 2

GRUPO 2 *Contra as Regras estabelecidas na RN nº 482/Aneel*				
Ator	*Setor da Sociedade*	*Representação*	*Principais Argumentos*	*Principais interesses*
Aneel	1° Setor	Sociedade	A mudança das regras é necessária para garantir que o sistema continue a crescer de forma sustentável, sem impactar os demais consumidores	Diminuir o incentivo à utilização de GD em prol de benefícios econômicos para as concessionárias de energia (lobby)
TCU	1° Setor	Sociedade	"As regras para utilização de GD precisam ser construídas em bases sólidas que não reduzam a eficiência à custa de outras bases do setor elétrico, principalmente os consumidores de baixa renda" (ALOÍSIO NETO, 2021)	Diminuir o incentivo à utilização de GD em prol de benefícios econômicos para as concessionárias de energia (lobby)
Marcelo Ramos	1° Setor	Estado do Amazonas	As regras estabelecidas na RN nº 482 não têm previsão legal e configuram um "subsídio cruzado", no qual o "mais pobre" paga pelos custos "dos ricos"	Diminuir o incentivo à utilização de GD em prol de benefícios econômicos para as concessionárias de energia (lobby)
Lafayette de Andrada	1° Setor	Estado de Minas Gerais	O SCEE estabelecido na RN nº 482 não é o ideal em termos de justiça	Conciliar os interesses das concessionárias de energia com os interesses do setor solar

Fonte: Elaboração própria, 2022.

Esse grupo entende que o SCEE estabelecido na RN nº 482 gera prejuízos aos não usuários de GD, pois transfere custos, não pagos pelos usuários de GD, para a parcela "mais pobre" da população. De acordo com esse Grupo, essa redução da tarifa para usuários de GD gera impactos nos custos de manutenção das redes de transmissão, uma vez que a tarifa também remunera esses custos. Nesse sentido, o Grupo 2 se posiciona contra o SCEE estabelecido na RN nº 482.

4 DISCUSSÃO

Embora o SCEE permita a redução e até anulação de tarifas elétricas, os consumidores geradores continuam pagando pela taxa de disponibilidade, encargos e iluminação pública. É com base nessa relação que o Grupo 1 se posiciona a favor da manutenção do SCEE, principalmente por sua importância para a geração de energia fotovoltaica no país e por possibilitar contribuições ainda maiores para a matriz elétrica brasileira.

Além dos benefícios ambientais gerados pela ampliação do uso da fonte solar, o Grupo 1 também relaciona a normativa e o SCEE com os "mais de 233 mil empregos e mais de 39,8 bilhões de novos investimentos" (BAITELO, 2021) no Brasil, desde a publicação da normativa. Além disso, a movimentação desse mercado também é capaz de gerar renda adicional para a população e promover uma economia mais justa e inclusiva (KALOGIROU, 2004; MARTINS, 2017; VIEIRA, 2016).

Esse Grupo reconhece a importância do SCEE e de um marco regulatório para o setor. E considera a ausência desse instrumento a principal barreira para o avanço da fonte solar no Brasil. Países como a Alemanha, Itália, Japão, Espanha e Estados Unidos, por exemplo, investiram em políticas públicas e programas de incentivo para ampliar o uso de sistemas fotovoltaicos, com foco principal na descentralização elétrica (MACHADO; MIRANDA, 2015).

A Alemanha, por exemplo, implantou sua política de maior notoriedade em 1998, para a instalação de 1.000 sistemas fotovoltaicos no país (PUIG; JOFRA, 2007). Já na Califórnia, o governo torna obrigatório o uso de sistemas fotovoltaicos em novas construções (RHODES, 2020; WEDY, 2021). A literatura demonstra que países líderes em capacidade solar instalada investem em planos para a expansão da fonte solar há pelo menos 20 anos (PUIG; JOFRA, 2007; SHARMA; TIWARI; SOOD, 2012; WEDY, 2021).

Além disso, outros atores desse Grupo também relatam os benefícios da fonte solar para a estabilidade do sistema elétrico brasileiro. Um exemplo é aproveitar a fonte para um suporte elétrico mais massivo, e contar com as hidrelétricas para suprimento durante as "ausências" da fonte solar, e de outras renováveis (SILVA, 2021). Uma vez que "essas fontes, por mais que sejam intermitentes, contribuem para a segurança, estabilidade e confiabilidade do sistema elétrico brasileiro" (SILVA, 2021).

Por outro lado, os argumentos apresentados acima não foram considerados pela Aneel e o TCU (Grupo 2) no momento das análises para a revisão da normativa. Os dois órgãos alegaram que têm como responsabilidade a regulação do setor e a auditoria de contas da União, e que benefícios socioeconômicos e ambientais deveriam ser matéria exclusiva do Congresso Nacional mesmo que esses órgãos tenham como beneficiário final a sociedade, e que o avanço da fonte solar, principalmente por meio da GD, traga benefícios para o Sistema Interligado Nacional (SIN) – regulado e fiscalizado também pela Aneel.

Segundo os resultados dos estudos apresentados pelo TCU, o SCEE fornece subsídio ao usuário de GD, pois, teoricamente esse usuário não paga pelo excedente de energia produzida injetada de volta à rede, além de ter a tarifa mensal elétrica praticamente zerada, o que em tese deixa de remunerar as concessionárias de energia elétrica. Com isso, o TCU apresentou preocupações acerca dos gastos até 2035 com a continuidade desse subsídio.

Entretanto, a estimativa desses gastos não tem previsão de saída dos cofres públicos, e sim das concessionárias de energia, que teoricamente deixariam de receber essa receita. Além disso, o parecer do Tribunal sobre a normativa parece se preocupar com a regulação de temáticas do mercado privado, e que, por sua vez, não deveriam ser o objeto de estudo do órgão.

Corroborando esse estudo, o deputado Marcelo Ramos entende que a ausência de remuneração das concessionárias gera mais gastos para a manutenção das redes de distribuição. Nesse caso, esses custos são repassados para as tarifas dos consumidores tradicionais, não usuários de GD. Esse argumento é corroborado também pelo estudo de Eid (2014), que apresenta possíveis consequências da implantação de sistemas de *net-metering*[1] a partir de energia solar, apesar de reconhecer sua importância para a redução da emissão de GEE e para a mitigação dos efeitos da mudança do clima.

Entretanto, Brown (2017) aponta que ainda que os custos do *net-metering* sejam repassados às concessionárias de energia, esse "prejuízo" é compensado pelos benefícios que a energia solar traz para estas, como, por exemplo: as reduções de gastos com geração, transmissão, distribuição e gestão de suas próprias redes, além da redução de externalidades negativas ao meio ambiente e

por consequência à sociedade, e da substituição de sistemas centralizados de geração de energia (BROWN, 2017).

É com base nesses argumentos que o Grupo 2 entende que o SCEE é um mecanismo de subsídio cruzado, no qual os não usuários de GD pagam pelas tarifas dos usuários de GD. Com base nisso, Marcelo Ramos classifica a RN nº 482 como uma "política de *Robin Hood* às avessas", onde o "pobre" paga parte da conta do "rico".

O Grupo 1 enxerga justamente ao contrário dessa relação, que os benefícios da GD não seriam apenas para os próprios geradores e usuários, e sim para a sociedade, principalmente para o sistema elétrico brasileiro, uma vez que com a diminuição de consumidores cativos nas redes convencionais, há também a diminuição da necessidade de manutenção e novos investimentos em redes de transmissão e distribuição, transformando o consumo elétrico cada vez mais local e descentralizado. Além da injeção da energia excedente direta à rede (BROWN, 2017).

Ademais, a utilização da fonte solar possibilita novos planejamentos e "otimização de novos investimentos em geração, transmissão e distribuição da energia" (MARTINS, 2017, p. 12).

Portanto, para o Grupo 1, a crescente instalação de sistemas fotovoltaicos é cada vez mais interessante para a segurança energética (e ambiental) do Brasil e para a autonomia de seus consumidores, gerando efeitos positivos para a rede e principalmente para a sociedade (BROWN, 2017). Por outro lado, o Grupo 2 enxerga esse aumento de instalações como um "círculo vicioso" para o lucro das concessionárias.

É dessa discussão que nasce a ideia de "taxar" o excedente de produção não consumido e injetado na rede. O Grupo 1 enxergou essa possibilidade como um obstáculo e desincentivo ao usuário de GD, alegando que a proposta não condizia com a realidade e potencial de irradiação do país, além de se configurar como um retrocesso às questões ambientais, principalmente no contexto das mudanças climáticas, que tornam os sistemas elétricos ainda mais vulneráveis. A posição desses atores é de que o governo deveria estimular ainda mais a adesão à energia solar, apresentando incentivos e novas propostas, com o objetivo de tornar seu sistema de abastecimento mais confiável e estável, além de considerar a importância da fonte solar para a demanda energética no país e na matriz mundial (KABIR, 2018).

Inclusive, apresentam estudos comparativos entre subsídios aplicados à sociedade pelo governo para aumentar o uso da fonte solar, como na Califórnia. Ali, "o governo subsidia cerca de 80% dos custos, provém segurança jurídica por 20 anos para o SCEE e apresenta outras legislações ainda mais impressionantes" (PINTO, 2021).

Em países como a Alemanha, por exemplo, o governo considera a geração distribuída por fonte renovável mais cara do que a fornecida pela rede. E, por isso, remunera o produtor pelo excedente gerado, pelo sistema de tarifa-prêmio – *feed-in-tariff* (FIT) (MACHADO; MIRANDA, 2015). O mesmo instrumento é utilizado na Austrália, embora com um incentivo a mais, uma vez que a tarifa-prêmio australiana considere o total bruto de geração para a remuneração do produtor, por 20 anos desde a data de implantação da política (LAMARCA JÚNIOR, 2012).

Já nos Estados Unidos, o governo propõe uma redução no imposto de renda de pessoa física ou jurídica de até 30% para usuários de geração distribuída com sistemas fotovoltaicos – instrumento Crédito Fiscal ao Investimento (ITC) (CALAZANS, 2016; WEDY, 2021), além do Sistema Modificado de Recuperação Acelerada de Custos (Macrs), que prevê a recuperação de investimentos nos sistemas fotovoltaicos por meio de deduções anuais (CALAZANS, 2016; WEDY, 2021).

Há ainda outras modalidades de incentivos aplicados aos demais países para o incentivo da energia solar, como os créditos de impostos para investimentos; os programas de financiamento e investimentos

públicos; e os subsídios diretos de capital (LAMARCA JÚNIOR, 2012; TIMILSINA; KURDGELASHVILI; NARBEL, 2011). Além disso, há o sistema de *net metering* no qual o excesso da produção do sistema é vendido às companhias elétricas para que seja disponibilizado a outros consumidores (JEAN *et al.*, 2021; LAMARCA JÚNIOR, 2012; TIMILSINA; KURDGELASHVILI; NARBEL, 2011), e os padrões de portfólio de energias renováveis, que estabelecem metas para a participação de fontes renováveis para os fornecedores de energia (LAMARCA JÚNIOR, 2012; TIMILSINA; KURDGELASHVILI; NARBEL, 2011).

A literatura demonstra que as regras estabelecidas na RN Aneel nº 482 estão em conformidade, ainda que de maneira preliminar, com as principais políticas adotadas pelo mundo em relação ao fomento à fonte solar e à GD. Diversos países adotam combinações desses instrumentos para potencializar ainda mais seus resultados em termos de capacidade instalada.

Considerando todos esses aspectos apresentados, o PL 5.829, de 2019, foi mostrado com a intenção de estabelecer uma segurança jurídica para o setor e apresentar propostas menos rígidas para o SCEE do que as apresentadas pela Aneel. O debate público, com os diversos *slogans* e argumentos, durou dois anos, e criou um imposto sobre o excedente de energia elétrica gerado.

Diante da aprovação do marco regulatório, o Grupo 1 se mostrou satisfeito quanto à proposta de redação final, que contém regras mais justas e viáveis para o setor, embora os custos para os consumidores de GD tenham aumentado e os novos consumidores não encontrem o SCEE da maneira mais vantajosa.

O Grupo 2, por outro lado, apresentou ressalvas em relação à manutenção do SCEE e se mostrou insatisfeito quanto à redação final da Lei. Esses atores entenderam que a Lei ainda deixa em desvantagem as concessionárias, e a classificaram como não ideal, mas mais justa do que a RN nº 482.

Por outro lado, o marco não dialoga com a agenda de sustentabilidade do país – principalmente com a Agenda 2030 e o Acordo de Paris –, assim como não foi pensado de maneira integrada com os demais setores da sociedade que também exercem influência no setor.

A Agenda 2030 é composta por 17 Objetivos de Desenvolvimento Sustentável (ODS) e 169 metas integradas, que consideram as diferentes realidades e capacidades de desenvolvimento e de políticas dos países concordantes (MCCOLLUM, 2018; PEIXER, 2019; VASCONCELOS; MELLO, 2021). A emergência da Agenda se dá justamente para o alcance de um mundo com um meio ambiente seguro e protegido e com acesso universal à energia, de forma sustentável e confiável (ONU, 2015).

É com base nesse contexto que a discussão do marco regulatório poderia ter contemplado também os novos desafios de cooperação nacional e internacional para a busca de soluções inovadoras e integradas (MCCOLLUM, 2018; ONU, 2015; PEIXER, 2019), uma vez que a Agenda 2030 pressupõe um engajamento global, que contemple os governos locais e federais, a sociedade civil, universidades e centros de ensino e pesquisa, setor privado e todos os atores necessários para a implantação desses objetivos integrados, complexos e inovadores (ONU, 2015; PEIXER, 2019).

A centralidade do ODS 7 à Agenda deixa claro o quanto esse tema demanda esforços conjuntos e amplos de todos os setores da sociedade. O acesso à energia se correlaciona com a geração de novos empregos, abertura de novos mercados tecnológicos, possibilidades de inovação (AKTER *et al*., 2017; BERNARD; TORERO, 2015; BURNEY *et al*., 2017; CHAKRAVORTY *et al*., 2014; GROGAN; SADANAND, 2013; MCCOLLUM, 2018; PUEYO *et al*., 2013; RAO; 2013; VAN VUUREN *et al*., 2015) e "fomento do crescimento econômico de um país" (SCHWERHOFF, 2017, p. 3).

Do mesmo modo, o acesso à energia e uso de fontes renováveis também é tema central para a redução das emissões globais de GEEs (ANENBERG *et al*., 2013; CHERIAN, 2015; GAMBHIR *et al*., 2017; KRIEGLER *et al*., 2013; KRIEGLER *et al*., 2014; MCCOLLUM, 2018; RIAHI *et al*., 2015; RIAHI *et al*., 2017; ROGELJ

et al., 2013; VAN VUUREN *et al*., 2015). Essa contribuição tem ligação direta com as contribuições traçadas pelo Brasil no Acordo de Paris.

O Acordo de Paris, ratificado e vigorado em novembro de 2016, é considerado o maior acordo mundial a favor do clima (FALKNER, 2016; LACLIMA; OBSERVATÓRIO DO CLIMA, 2021; SOUZA; CORAZZA, 2017). Tem como objetivo estabilizar a temperatura global abaixo de 2°C, mantendo esforços para limitá-la a 1,5°C (FALKNER, 2016; LA CLIMA; OBSERVATÓRIO DO CLIMA, 2021; PEIXER, 2019; SECAF, 2016; SOUZA; CORAZZA, 2017). Para isso, os países se comprometeram a apresentar estratégias de longo prazo para a redução das emissões dos GEE, denominadas de Contribuições Nacionalmente Determinadas (NDCs) (FALKNER, 2016; REI; GONÇALVES; DE SOUZA, 2017; SOUZA; CORAZZA, 2017). A NDC brasileira se compromete a reduzir em 37% as emissões de GEE, até o ano de 2025, e em 43% até 2030, considerando todo o território e economia brasileira (BRASIL, 2015; PEIXER, 2019; REI; GONÇALVES; DE SOUZA, 2017).

Considerando que o setor de energia é o maior emissor de GEE no Brasil (responsável por 33% das emissões) (MENDES, 2020) e que os compromissos firmados demandarão esforços ainda maiores no setor, nas políticas públicas e nos planejamentos realizados pelo governo, a discussão acerca da Lei nº 14.300/2022 poderia ter sido aproveitada para o planejamento dessas ações, principalmente ligadas à possibilidade da expansão da fonte solar e incentivos à utilização de novas fontes renováveis para que essas tenham cada vez mais competitividade e domínio de mercado. Vale ressaltar que a maior participação elétrica hoje é referente à fonte hídrica, o que torna a matriz energética limpa, porém, centralizada e pouco diversa.

5 CONCLUSÃO

Apesar dos benefícios socioeconômicos e ambientais, a geração distribuída de energia solar ainda enfrenta resistência para alcançar seu pleno potencial no Brasil. Isso acontece apesar dos compromissos estabelecidos pela Agenda 2030 e pelas NDCs, que apontam as estratégias de descarbonização da matriz elétrica mundial, por meio das diretrizes definidas por cada país. Com base nesses acordos, o Brasil assumiu compromissos de redução das emissões de GEE, entretanto, não estabeleceu nenhum plano de ação para que esse objetivo seja alcançado, seja considerando a expansão de novas fontes renováveis ou novas formas de geração, como as gerações descentralizadas.

Por outro lado, a partir do estabelecimento da Resolução Aneel nº 482/2012, a geração distribuída disparou no Brasil, e foi a responsável pelo aumento de capacidade instalada em níveis recordes da fonte solar no país. Apesar disso, os debates acerca da revisão da RN nº 482 não consideraram o caráter estratégico do tema, os custos de oportunidade e a economia aos cofres públicos ante a adoção de novas fontes na matriz elétrica. Desconsideraram também os compromissos internacionais, a agenda climática e do desenvolvimento sustentável. Os grupos atuantes se reduziram em discussões monetárias. Com isso, as disputas sobre o marco legal para a regulamentação do setor resultaram em retrocesso aos incentivos para a sua expansão.

Os debates até então não levavam em consideração o caráter estratégico da temática energética para o desenvolvimento social, bem como para a Agenda 2030 estabelecida mundialmente. Além de não considerarem a real necessidade de investimentos governamentais e planejamentos integrados para a ampliação de fontes não emissoras de GEE, como a fonte solar.

Dado esse contexto, o Brasil não propõe nenhum plano de ação integrado entre as diferentes agendas governamentais ou de transição para economias de baixa emissão de carbono e para a transformação de cidades sustentáveis no horizonte 2030-2050, desconsiderando, portanto, a centralidade da temática energética para o alcance dos compromissos da Agenda 2030 e do Acordo de Paris.

NOTA

1 | Política que permite a compensação de parte ou da totalidade de eletricidade autogerada. O sistema possui um medidor que é capaz de identificar quando um consumidor autogerador consome mais e menos energia do que produz. Quando há menor consumo diante da produção, os produtores recebem benefícios que funcionam como créditos de energia (POULLIKKAS; KOURTIS; HADJIPASCHALIS, 2013).

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Who pays the price? Socio-ecological controversies regarding the energy transition in South America

Quem paga o preço? Controvérsias socioecológicas associadas à transição energética na América do Sul

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ABSTRACT

Transformations linked to more sustainable energy and economic systems may have societal and ecological costs, which some people and territories must assume. Controversies might emerge associated with developing new productive chains, e.g., transition mineral activity. This study examines the relations among energy transition, society, and the environment, focusing on copper as a high-tech mineral and considering Bolivia, Chile, and Peru, three countries with mining-dependent economies. This work tries to see if countries are becoming more renewable, efficient, and modern and if this correlates with copper activity and societal factors. As a result, Bolivia has pending tasks on both the energy demand and production sides. Despite presenting good performance on renewables and efficiency, Chile and Peru have pending tasks associated with the ecological distribution regarding mining and energy sectors. Mining-based economies might expose the fragility of green transitions in meeting sustainable goals considering equality, justice, and ecosystem care.

Keywords: Energy transition. Extractivism. Just transitions. Natural boundaries. Societal boundaries. South America.

RESUMO

As transformações ligadas à busca por sistemas energéticos e econômicos mais sustentáveis poderiam trazer custos sociais e ecológicos que algumas comunidades e territórios devem suportar. Além disso, podem surgir controvérsias relacionadas com o desenvolvimento de novas cadeias de produção, por exemplo, a atividade industrial associada à exploração e produção dos minerais de transição. Este estudo examina as relações entre transição energética, sociedade e o meio ambiente, focando o cobre como mineral de alta tecnologia, e considerando como casos de estudo a Bolívia, o Chile e o Peru, três países com economias dependentes da mineração. Tenta-se explorar se os países estão se tornando mais renováveis, eficientes e modernos, e se isso está correlacionado com a produção de cobre e fatores sociais. Como resultado, a Bolívia tem pendências tanto na demanda quanto na produção de energia. Apesar do bom desempenho histórico das energias renováveis e da eficiência energética, o Chile e o Peru têm questões a serem resolvidas relacionadas à distribuição ecológica, concernente aos setores

de mineração e energia. As economias baseadas na mineração poderiam evidenciar a fragilidade das transições verdes para alcançar objetivos transversalmente sustentáveis, levando em conta a equidade, a justiça e o cuidado com os ecossistemas.

Palavras-chave: Transição energética. Extrativismo. Transições justas. Limites naturais. Limites sociais. América do Sul.

1 INTRODUCTION

The sustainable energy transition has become pivotal in the current decarbonization of economies to face and mitigate climate change. Regarding energy production, matrices have begun to include increasingly low-carbon sources to substitute fossil fuels. On the other hand, according to the Intergovernmental Panel on Climate Change (IPCC), electricity is raising its share of end-use energy – the electrification of the economy (IPCC, 2022). According to the International Energy Agency (IEA), clean electricity and electrification are central to reaching a net zero emissions global system (IEA, 2022a). This implies developing new clean technology and production chains. Critical commodities to the development of technology for sustainable transitions are called "high-tech" metals or "transition minerals" (VOSKOBOYNIK; ANDREUCCI, 2022). Calvo and Valero (2021) found 13 prospectively critical elements to sustainable energy technology: tellurium (Te), silver (Ag), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), gallium (Ga), indium (In), lithium (Li), manganese (Mn), nickel (Ni), tin (Sn), and zinc (Zn). The countries with the highest production of these minerals are the People's Republic of China (Zn, Te, Sn, In, Ga, Cd), Indonesia (Ni), South Africa (Cr, Mn), Australia (Li), the Democratic Republic of the Congo (Co), Chile (Cu), and Mexico (Ag).

Latin America and the Caribbean (LAC) play a crucial role in the global sustainable energy transition since countries such as Chile and Peru are global leaders in copper production. Mexico leads in silver production, and Bolivia, Argentina, and Chile share one of the most extensive lithium reserves in the world (the lithium triangle). In addition, Brazil and Mexico remain economically dependent on hydrocarbons since they are among the most prominent producers in the world. However, the energy and mining industries historically have stimulated socio-ecological conflicts, whereas profits and benefits have failed to benefit everyone equally (BORDERA et al., 2022; POQUE GONZÁLEZ; SILVA; MACIA, 2022).

LAC energy and mining cases expose a critical paradigm. Nature limits the economy! As Meadows *et al.* (1972) advertised, unsatisfied human necessities exist, and nonrenewable natural resources – such as fossil fuels and minerals – are finite. As Nicholas Georgescu-Roegen claims, following the second thermodynamic law, industrial economic growth, as known today, presupposes a growing use of mass and energy. Moreover, economic activity spreads waste into the environment (Figure 1). Some (not all) of the used materials (inputs) can be recycled (CECHIN, 2010), but energy cannot, as it is dissipated (MARTINEZ-ALIER *et al.*, 2016).

In summary, global industrial economic activity inevitably needs matter and/or energy, and as described by Max-Neef (2010), "the economy is a subsystem of a larger and finite system, the biosphere" (Figure 1). Then, we might presuppose that energy transition inevitably needs materials to be carried out. Later, what is the relation between energy transition and society, the economy, and the environment? What are the natural limitations outlining sustainable energy transitions?

This study assesses the relations and controversies among sustainable energy transition, society, and the environment. As a critical transition mineral, copper is chosen to explore these relations. The focus is on LAC copper-producing countries – Bolivia, Chile, and Peru – as the objects of study. The structure of this work comprises Section 2, which focuses on integrating concepts; Section 3 shows the methodology used; and Section 4 exposes our main results. Finally, Section 5 articulates an interdisciplinary discussion, and Section 6 concludes and stimulates new research on this topic.

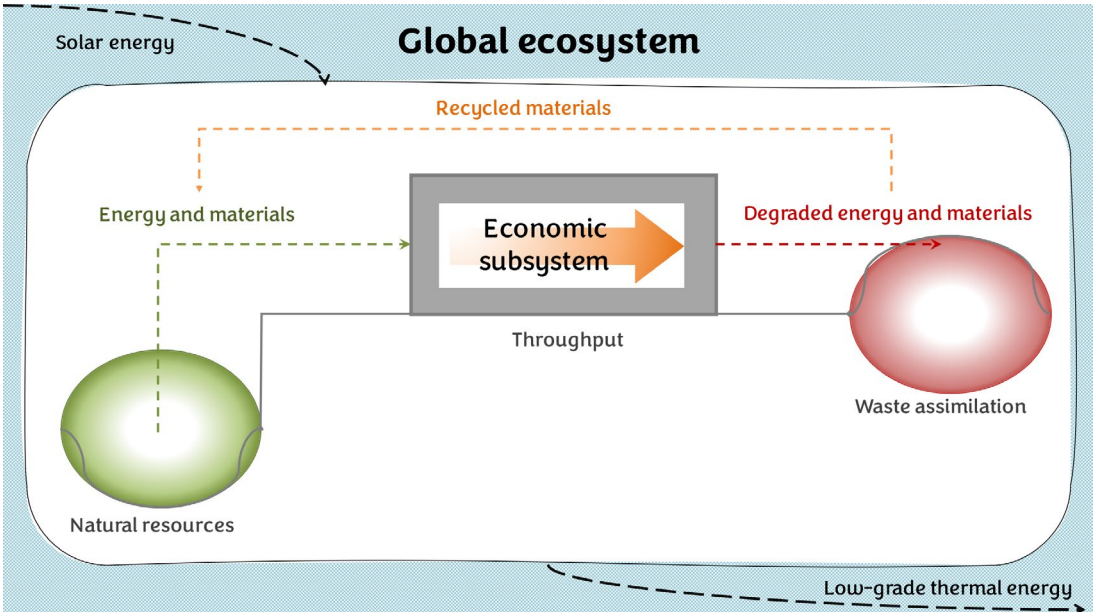

Figure 1 | Nicholas Georgescu-Roegen's economy model

Source: Created by the author based on Cavalcanti (2012) and Cleveland & Ruth (1997).

2 CONTEXTUALIZATION – CRISIS TIME AND THE FRONTIERS OF THE ENVIRONMENT

Governmental efforts to face and mitigate climate change in the last three decades have not been sufficient (DUNLAP, 2023)socio-ecological problems are nothing new. Despite all efforts to resolve environmental dilemmas, socio-ecological catastrophe has only intensified. Governments, in response, have unveiled the green economy to confront ecological and climate catastrophe. The green economy, however, has worsened socio-ecological conditions, invigorating the present trajectory of (techno. The IPCC claims that meeting the temperature goals of the Paris Agreement (1.5 - 2°C) implies intense efforts toward a net-zero economy (IPCC, 2022). In 2022, considering what governments are doing to reach the targets and objectives they have set out, the IEA (2022a) estimates a trend for the rise in average temperatures to be approximately 2.5°C in 2100 (with a 50% probability).

The world economy recently suffered the effects of the Covid-19 pandemic, triggering a complex context that changed the patterns of connectedness and causality among several financial and commodity markets. Later, in 2022, the Ukrainian–Russian Federation conflict stimulated a new overlapped stage of uncertainty and volatility in global commodity markets (ADEKOYA et al., 2022; ALI et al., 2022; BORDERA et al., 2022; IGLESIAS; RIVERA-ALONSO, 2022). To the IEA (2022a), "the crisis has stoked inflationary pressures and created a looming risk of recession."

The desperation to improve socioeconomic conditions and overcome financial crises can often encourage forgetfulness about the boundaries of Nature[1] (CAVALCANTI, 2012), mainly in commodity-dependent economies. Encouraged by the attempt to drive short-term political plans toward an economic recovery in line with industrial economic growth, countries could abandon the low-carbon pathways, threatening the biophysical limits of the Earth (AVIS, 2022). As described by Martinez-Alier (2022), the industrial economy is entropic, and therefore, it goes to the frontiers of commodity extraction and waste disposal, causing damages and conflicts. Recall that energy dissipates; meanwhile, only some materials can be recycled (Figure 1).

2.1 A JUST ENERGY TRANSITION AND ECOLOGICAL DISTRIBUTION

"Just as addressing climate change is a prerequisite for redressing global injustice, delivering climate action in an equitable and just way is a prerequisite for the success of the transition" (CRONIN *et al*., 2021). According to the IPCC, this just transition would guarantee a set of principles, processes, and practices to include all people, workers, places, sectors, countries, or regions in moving from a high- to a low-carbon economy. Social protection, democracy, dialogue, well-being, equity, and justice are critical. Additionally, processes must respect vulnerable groups and their dignity (IPCC, 2022).

Energy systems and economic configurations often spread inequalities and injustice among societies. For instance, some net fuel exporting countries have high levels of energy poverty (KNOX *et al*., 2022) a growing body of literature has started to examine the (in. Currently, between 35 and 40 million people in LAC lack access to essential energy services, such as electricity and modern fuels (GUZOWSKI; MARTIN; ZABALOY, 2021). The *energy justice* concept emerged as a framework to discuss local and global issues of fairness among people concerning energy supply, production, and consumption (IWIŃSKA; LIS; MĄCZKA, 2021).

Environmental justice emerges from the debate about *ecological distribution*. It refers to the unequal repartition of the environmental costs and potentials resulting from economic activity. Furthermore, it points to social, spatial, and temporal asymmetries in using environmental resources and services. Currently, it is associated with decreased natural resources, biodiversity loss, pollution, scarcity, degradation, and the quest for a sustainable future (LEFF, 2013).

2.2 EXTRACTIVISMS

Following Gudynas (2017), "extractivism" is extracting natural resources in high intensity or volumes and exporting at least half of the extracted resources to global markets as commodities or raw materials. Since the 2000s, the expression "neo-extractivism" has become linked to progressive LAC governments. In neo-extractivism (also called 21st-century extractivisms), states play a decisive role in fostering extractive activities. The political establishment argued the legitimacy of their involvement by promoting progressive social development via the profits from extractive activities. Nevertheless, extractive activities stimulated socio-ecological conflicts, evincing the inequitable ecological distribution in LAC (SVAMPA, 2021; VILLALBA-EGUILUZ; ETXANO, 2017).

2.3 A BRIEF INTRODUCTION TO THE LAC ENERGY TRANSITION

According to the Latin American Energy Organization (Olade), in 2020, 36.3% of LAC electricity was produced by fossil fuels. Moreover, 20% of LAC end-use energy came from electricity, whereas 50% came from oil and its derivatives (OLADE, 2022b). In addition, subregions such as Central America or the Caribbean import more than 70% of the total oil used and its derivatives (OLADE, 2022a), making them vulnerable to the volatility of global markets (GROTTERA, 2022). Some LAC countries have recently transitioned to nonconventional renewable energies (NCRE)[2]. In 2005, Belize, Costa Rica, El Salvador, Guatemala, and Nicaragua generated more than 10% of their national annual electricity from solar, wind, geothermal, and renewable thermal sources. In 2020, this list also included Uruguay, Brazil, Chile, Honduras, and Mexico. Costa Rica and Uruguay practically decarbonized their power production, and Paraguay is almost entirely hydroelectric-dependent (POQUE GONZÁLEZ; SILVA; MACIA, 2022).

2.4 TRANSITION MINERALS – THE COPPER CASE

According to the IEA, the demand for transition minerals might rise twofold to fourfold by 2030 due to the expanding deployment of renewables, electric vehicles (EVs), battery storage, and electricity networks. Thus, copper use might increase meaningfully in terms of absolute volumes. The current demand of approximately 6 million tons (Mt) per year might increase to 11 Mt to 16 Mt by 2030. On the other hand, the recycling of transition minerals is underutilized, considering that 95% of solar panel components by mass are recyclable, similar to wind turbines (IEA, 2022a).

3 THEORY, MATERIALS, AND METHODS

This study focuses on copper, considering its role as one of the most prospective critical transition minerals (CALVO; VALERO, 2021; IEA, 2022a). Furthermore, it contemplates the Andean countries Bolivia, Chile, and Peru, which have highly mining-dependent economies (ERICSSON; LÖF, 2019) with copper production. From these cases, the study explores the relationship between energy transition, the environment, society, and the exploitation of copper. Then, this section shows some characteristics of the countries studied and, after, the methodological course.

3.1 CASE STUDIES

Chile had the most extensive copper reserves worldwide in 2020, with 200 million tons, or 23% of the world's total, whereas Peru had 11% (CANADA, 2022). Concerning energy, Bolivia has a relatively inefficient economy since it needs more energy to produce one gross domestic product (GDP) unit. Bolivia also uses small shares of electricity as final-use energy. Table 1 introduces these neighbouring countries.

Table 1 | National profiles

Parameter	*Bolivia*	*Chile*	*Peru*
2020 GDP per capita (constant 2015 USD)	2,986.0	12,890.3	5,807.1
2020 mining GDP (% of GDP)	7.1	6.1	3.9
2019 renewable supply of primary energy (%)	11.2	33.8	25.1
2019 energy intensity[a]	1.65	0.74	0.73
2020 electrification of the economy (% electricity in final use)	12.0	22.0	20.9
2020 access to electricity (%)	93.7	99.7	97.0
2018 GHG per capita (tCO_{2e} per capita)	5.0	5.9	3.0

a| Final energy consumption (in thousands of barrels of oil equivalent)/GDP in USD millions (at constant 2010 prices).

Source: Data from Olade (2022a), United Nations (2021) and World Bank (2022).

3.2 METHODOLOGICAL COURSE

This study looks for tendencies toward low-carbon energy systems, contrasting them with societal lacks, ecological threats, and socioenvironmental conflicts associated with the power and copper mining sectors. The behaviour and relationships of each country over time were evaluated by four qualitative and quantitative stages, namely:

i. Three data series were used to comparatively analyze shifts in energy source use and energy consumption, namely, the share of primary renewable energy (1970-2019), the share of electricity as end-use energy (1970-2020), and the share of renewable sources to produce power (2000-2020). Data is from the UN (2021) and Olade (2022a). This stage explores

how renewable and efficient (or not) countries have become over time. Renewable shares in all the energy the country has at its disposal yearly show if fossil fuels are phasing out. The proportion of electricity in all final-use energy every year indicates that countries are participating in the electrification of economies' global process. Finally, the introduction of NCRE in power generation since the 2000s reveals whether countries are more modern, clean, and efficient.

ii. The socioeconomic evaluation contrasted copper mining activity indicators with national social conditions. It considers copper production (1990-2020), copper price (1990-2020), and national GDP per capita (1970-2020). This stage searched national (such as public ministerial information) and global databases (such as the World Bank). The primary purpose of this stage is to explore the benefits of mining in economies and societies.

iii. A qualitative assessment explores the relationship among energy and copper mining sectors, the environment, and society from the emergence of socio-ecological conflicts documented in the Atlas of Environmental Justice (EJAtlas) (MARTÍNEZ-ALIER, 2020; TEMPER; BENE; MARTINEZ-ALIER, 2015). It aims to map and understand the socio-ecological dimensions of copper mining and power sector development.

iv. The information shown in the three previous stages was cross-checked, seeking interrelations via Pearson's correlations among energy transition, societal variables, and copper mining activity over the 21st-century window (2000-2019). Nine variables describe the behaviour of these study fields over time in every country (Table 2). Pearson's correlation coefficient looks for correspondences, contradictions, or controversies in Bolivia, Chile, and Peru regarding the relation between the transformation of energy sources, socioeconomic attributes, and copper production. Finally, a matrix containing Pearson's coefficients for every relation among variables is elaborated for each country.

Note that Pearson's correlation coefficient assumes a value between −1 and 1, in which 0 refers to no correlation, 1 is an entirely positive correlation, and −1 is an utterly negative correlation. Additionally, a 0.7 correlation value between two variables indicates a significant positive relationship. A positive correlation means that as variable A increases, so will variable B, whereas if the correlation value is negative, B will decrease as A does (NETTLETON, 2014). Then, from the nine variables, this work explores if, since the 2000s, countries are turning more renewable, clean, modern, and efficient and if this correlates with population growth, national incomes, copper production, or copper prices.

This work uses mainly secondary data, which are duly referenced. Consequently, there are no ethical compromises or transgressions.

Table 2 | Data series

Variable	*Code*	*Unit*	*Source*
Access to electricity	EA	% of population	Olade (2022a)
Electrification of the economy	EE	% of final energy	Olade (2022a)
Renewable primary energy	RPE	% of energy	UN (2021)
Renewable-produced electricity[a]	REWH	% of electricity	Olade (2022a)
Final energy consumption	EC	1012 Cal	Olade (2022a)
Population	PO	Thousands of people	UN (2021)
GDP	GDP	Constant 2015 USD	World Bank (2022)

Variable		Code	Unit	Source
Copper production	Bolivia	CUT	Metric tons	INE (2022)
	Chile			Cochilco (2022)
	Peru			Ministerio de Energía y Minas (2022)
Copper price[b]		CUUSD	USD per pound	Macrotrends (2022)

a | Without hydropower. b | Year-end closing price.

Source: Elaborated by the author.

4 INTO THE ENERGY – SOCIETY – ENVIRONMENT TRIAD IN BOLIVIA, CHILE, AND PERU

4.1 WHAT ABOUT ENERGY SOURCES?

Figure 2 shows that Bolivia and Peru's primary energy increased their shares of nonrenewable sources. Only 11 of every 100 units of primary energy in Bolivia came from renewable sources in 2019; meanwhile, Chile maintained a mixed matrix over time. According to the 2020 energy balance, Bolivia exports approximately 74% of its natural gas production. On the other hand, Chile imports 98% of its oil, 80% of its natural gas, and 89% of its mineral coal. Peru is an intermediate case since it exports 31% of its produced natural gas while importing 28% of its oil and 62% of its coal (OLADE, 2022a). In other words, Chile is highly vulnerable to international fossil fuel markets.

Regarding the electrification of their economies, Chile and Peru increased electricity as end-use energy between 1970 and 2020 (Figure 3). On the other hand, although Bolivia shows a smooth tendency to raise electricity as an end-use, only 12 of every 100 units of energy it consumed came from electricity in 2020. Note that the world is at approximately 20% today, and if current tendencies continue, this will increase to 22% by 2030 and 28% by 2050 (IEA, 2022a). In sum, Bolivia needs technological improvements on the demand side.

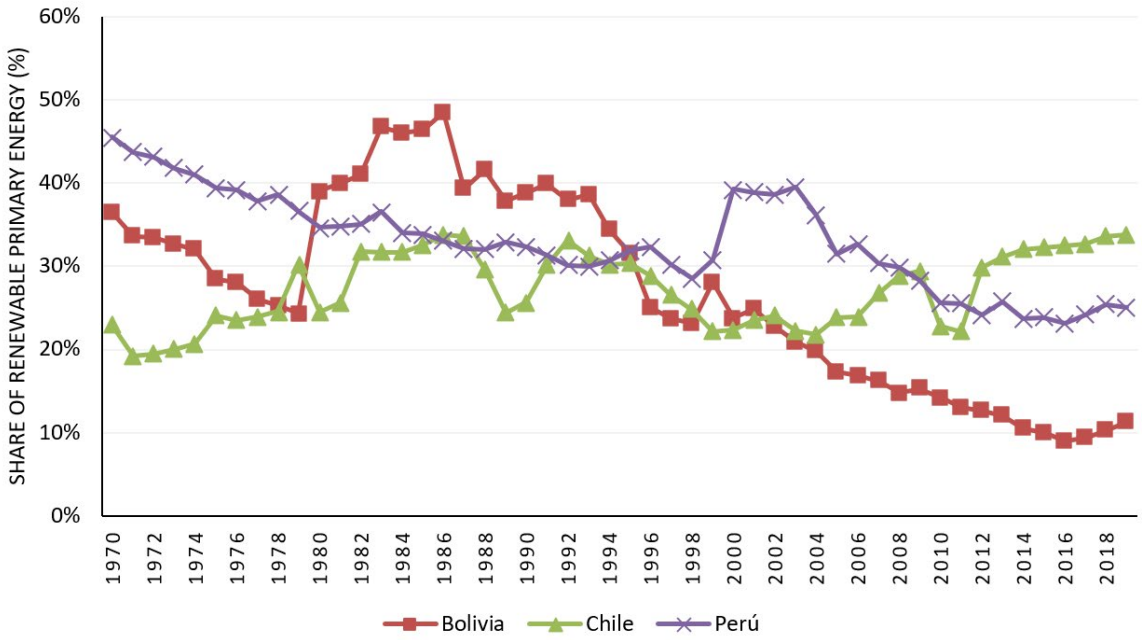

Figure 2 | Share of renewable sources in primary energy (1970-2019)

Source: UN (2021).

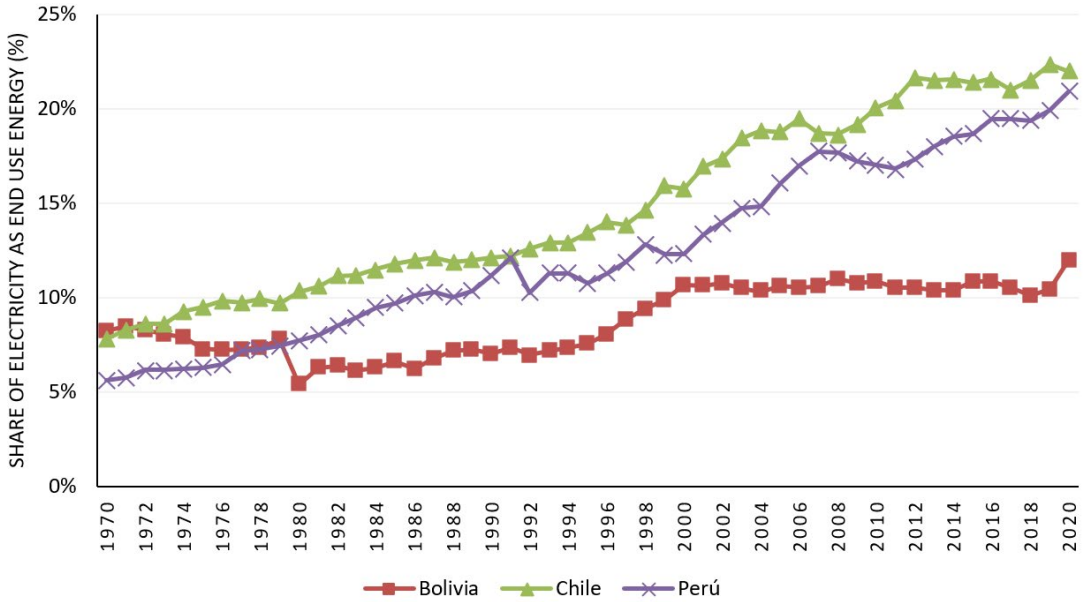

Figure 3 | Share of electricity as end-use energy (1970-2020)

Source: Olade (2022a).

Power generation introduced NCREs in the 21st century (Figure 4). If we consider hydroelectricity (strong colour series in Figure 4), Chile has maintained approximately 50% of its production by renewable sources during the 21st century. Nevertheless, Bolivia and Peru reduced their share of renewable power production over time, reaching 64% and 35% in 2020, in contrast to 81% and 54% in 2000, respectively. If we disregard hydroelectricity (and consider only solar, wind, geothermal, and biomass sources), only Chile progressed markedly in this transition, reaching 22% of its share of produced electricity in 2020 (Figure 4). Bolivia and Peru generated only approximately 6% from solar, wind, geothermal, and biomass sources (OLADE, 2022a). There is a lack of NCRE implementation in both Bolivia and Peru.

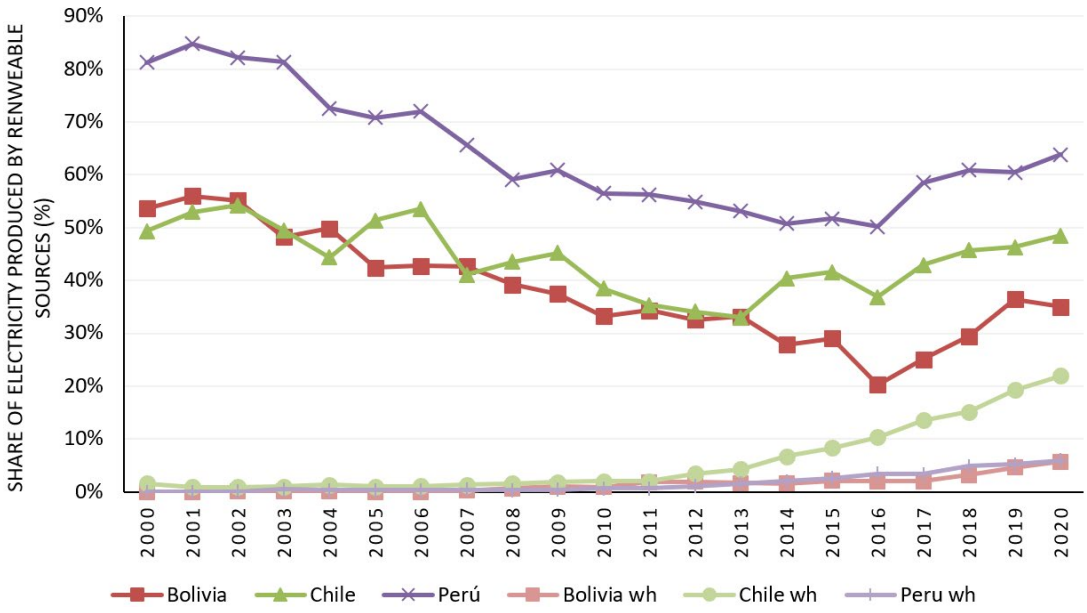

Figure 4 | Share of yearly power production by renewable sources (2000-2020)

Note: To distinguish the importance of hydroelectricity, the strong colour series consider hydroelectricity, renewable thermoelectricity, and solar, wind, and geothermal sources. The light colour series (using the "wh" mark = without hydro) show the data ignoring hydroelectricity.

Source: Olade (2022a).

4.2 A BRIEF POINT ON SOCIOECONOMIC ISSUES

Copper production has been a critical player in Andean South American economies. Figure 5 shows that Chile and Peru drastically increased copper production between the 1990s and 2020 (COCHILCO, 2022; MINISTERIO DE ENERGÍA Y MINAS, 2022). According to the National Institute of Statistics, Bolivia jumped to over 2,000 metric tons of produced copper in the 2010s (INE, 2022). In parallel, international copper prices climbed in the 2000s (MACROTRENDS, 2022). According to the World Bank (2022), between 2006 and 2011, more than 10% of the Chilean and Peruvian GDP came from mining. In 2020, Chile and Peru had the world's largest and second-largest copper production, whereas China held the third position, with 28.5%, 10.9%, and 8.4%, respectively. In 2020, 50% of Chilean exports were copper, representing 85.5% of all Chilean mining exports (SERNAGEOMIN, 2021).

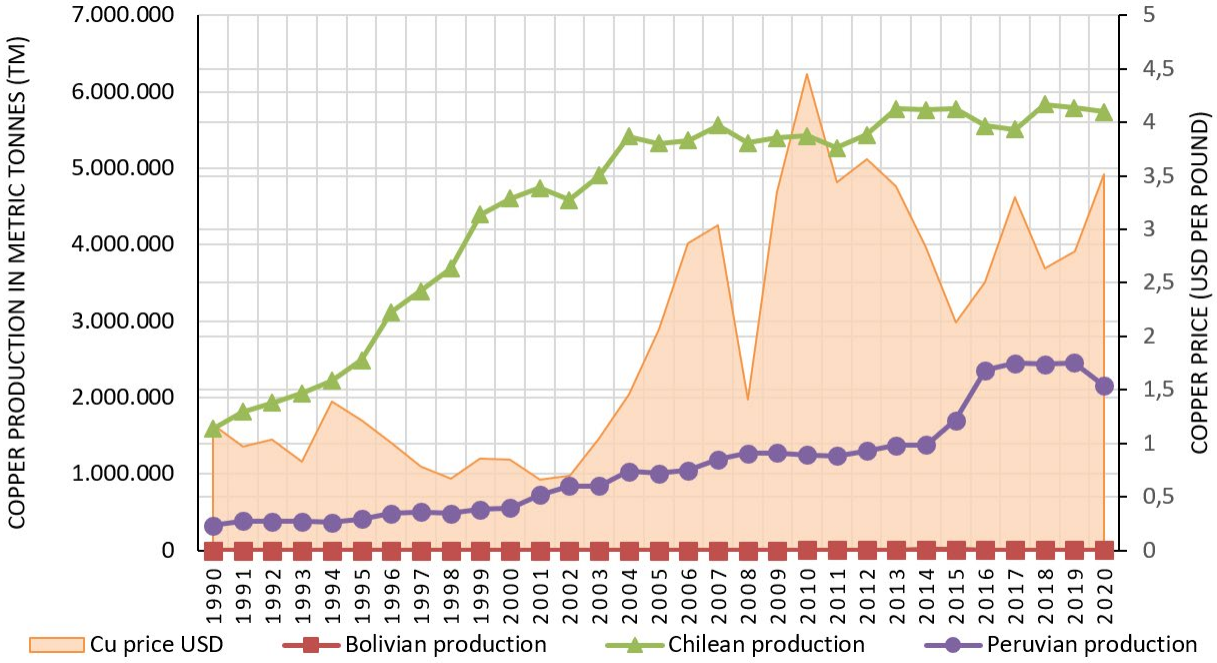

Figure 5 | Copper production (in metric tons) by country and price (USD per pound)

Source: Cochilco (2022); INE (2022); Macrotrends (2022); and, Ministerio de Energía y Minas (2022).

Despite their long-term increase in GDP per capita over time (Figure 6), these three countries face equity and poverty challenges. In 2020, the Chilean GINI[3] indicator was 0.475, above the Latin American average (0.464), consequently showing its pending task of distributing wealth. Conversely, Bolivia went from 0.635 in 2000 to 0.449 in 2020, showing an evolution regarding this task. In 2020, the Peruvian GINI indicator was 0.464. In 2020, Bolivia, Chile, and Peru had 32.3%, 14.2%, and 28.4% of their population living in poverty, respectively; the Latin American average was 33% (UN, 2021). If we consider the UN Sustainable Development Goals (SDG), Bolivia and Peru face challenges regarding SDG 7 – ensure access to affordable, reliable, sustainable, and modern energy for all – since a considerable part of their population lacks access to electricity (Table 1) (OLADE, 2022a; POQUE GONZÁLEZ; SILVA; MACIA, 2022). It also reveals the lack of energy justice in those countries because they are fossil fuel exporters.

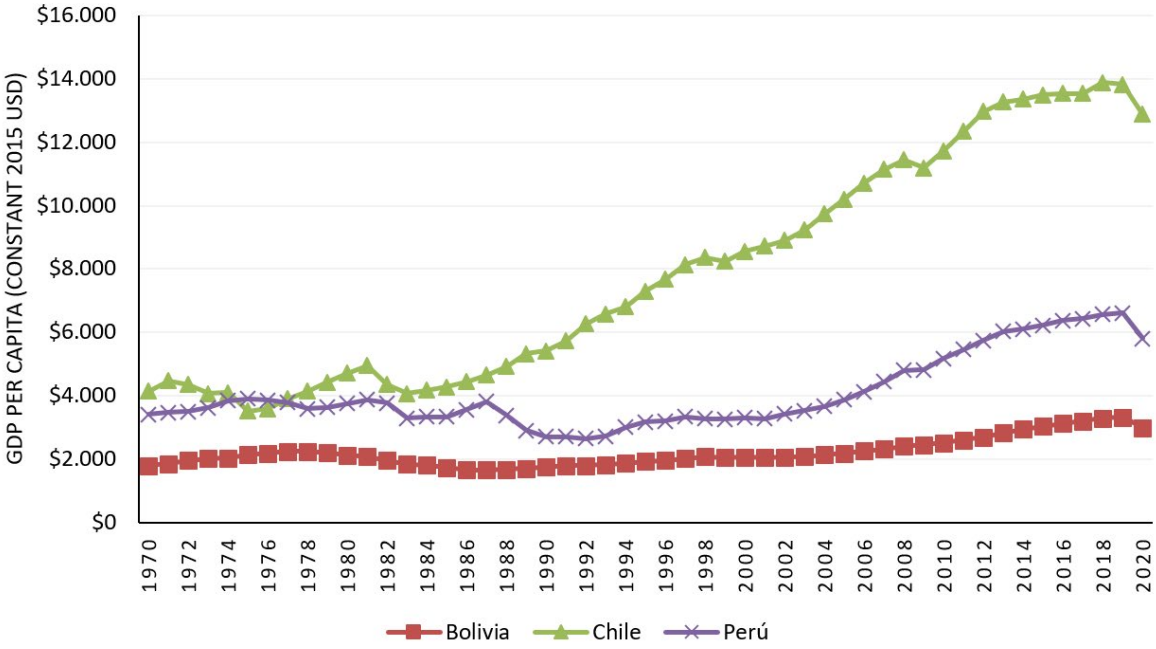

Figure 6 | GDP per capita (constant 2015 USD)

Source: World Bank (2022).

4.3 SOCIO-ECOLOGICAL ISSUES

According to the EJAtlas, copper mining is historically associated with the emergence of socio-ecological conflicts in Andean South America (Figure 7 shows a concentration of conflicting cases in the region). Bolivia has three conflicting cases associated with copper activity emerging in the 2010s, whereas Peru shows 29 cases, some of which have long-term origins. Both countries also face issues regarding silver, gold, and lithium extraction. Chile showed 21 conflicting copper mining issues, especially in its northern region.

In Chile, private companies are generally involved in the socio-ecological conflicts around the copper. Nevertheless, projects such as Dominga[4] were associated with corruption cases involving public government actors ignoring the environmental impacts of the activity. As transversal issues in all three countries, Indigenous people, peasants, and farmers are the main groups resisting critical mining projects. Additionally, water is a directly or indirectly disputed essential resource that opposes company interests against human necessities, social, cultural, and ecological heritage, and ecosystem preservation. Remarkably, the private figure of water rights in Chile, set by its 1981 Water Code, became a political issue driving disagreement (BUDDS, 2004).

Figure 7 | Socio-ecological conflicts around copper

Note: Colours identify the main type of conflict registered in the EJAtlas. Then, orange is: mineral ores and building materials extraction; cyan is: water management; red is: industrial and utility conflicts; light brown is: waste management.

Source: Temper, Bene, and Martinez-Alier (2015).

In addition to the disputes associated with copper mining, Bolivia and Peru face socio-ecological conflicts related to natural gas and oil extraction and processing. At the same time, Chile mainly shows conflicts associated with renewable and nonrenewable power-producing industries (Figure 8). Regarding fossil fuel activity, Bolivia has faced nine controversial oil and natural gas projects, whereas Peru showed 11 acute episodes and associated conflicts. Additionally, the local population has confronted two hydropower projects in Bolivia and eight in Peru.

Regarding fossil fuel exploitation, southern Chile has shown three controversial coal mining projects. Concerning power production, the EJAtlas reported four controversial projects associated with thermoelectrical power generation in central and northern Chile. Additionally, its population has faced 16 hydropower projects in its southern region. Finally, regarding NCRE, one geothermal project and two wind power production plants have triggered socio-ecological conflicts.

Figure 8 | Socio-ecological conflicts triggered by power projects

Note: Colours identify the main type of conflict registered in the EJAtlas. Then, orange is: mineral ores and building materials extraction; cyan is: water management; red is: industrial and utility conflicts; light brown is: waste management; yellow is: nuclear; black is: fossil fuels and climate/energy justice; grey is: infrastructure and built environment; green is: biodiversity and conservation conflicts; and, dark brown is: biomass and land conflicts.

Source: Temper, Bene and Martinez-Alier (2015).

4.4 CROSSING

As with the Pearson correlation, this item explores interrelations among energy transition, societal variables, and copper mining activity over the 21st century. In Bolivia, total energy consumption increased directly with its population, GDP, and copper production. In addition, access to electricity and the introduction of NCRE in power generation are positively correlated. As previously stated, the electrification of its economy and the share of primary renewable energy are pending tasks since they are not correlated with the economy's evolution, energy consumption, and demography. The renewable shares in primary energy are negatively correlated with all variables except electrification. Electrification does not correlate with any variable (Table 3).

Table 3 | Pearson matrix for the Bolivian series

Bolivia	*EA*	*EE*	*RPE*	*REWH*	*EC*	*PO*	*GDP*	*CUT*	*CUUSD*
EA		-0.186	-0.936	0.916	0.996	0.992	0.990	0.806	0.623
EE	-0.186		0.108	-0.283	-0.237	-0.215	-0.238	-0.166	-0.123
RPE	-0.936	0.108		-0.769	-0.934	-0.956	-0.914	-0.806	-0.713
REWH	0.916	-0.283	-0.769		0.915	0.907	0.926	0.659	0.4608
EC	0.996	-0.237	-0.934	0.915		0.993	0.996	0.823	0.5946
PO	0.992	-0.215	-0.956	0.907	0.993		0.988	0.796	0.6372

Bolivia	EA	EE	RPE	REWH	EC	PO	GDP	CUT	CUUSD
GDP	0.990	-0.238	-0.914	0.926	0.996	0.988		0.798	0.5415
CUT	0.806	-0.166	-0.806	0.659	0.823	0.796	0.798		0.4608
CUUSD	0.623	-0.123	-0.713	0.461	0.595	0.637	0.541	0.461	

Source: Elaborated by the author.

In Chile, total energy consumption is directly correlated with all variables except copper price, which has a smooth correlation. Copper price has no strong correlation with any variable. The stronger correlation is among total energy consumption, population, and GDP (Table 4).

Table 4 | Pearson matrix for the Chilean series

Chile	EA	EE	RPE	REWH	EC	PO	GDP	CUT	CUUSD
EA		0.922	0.763	0.627	0.909	0.892	0.926	0.927	0.713
EE	0.922		0.756	0.697	0.881	0.924	0.947	0.877	0.698
RPE	0.763	0.756		0.800	0.903	0.868	0.867	0.733	0.362
REWH	0.627	0.697	0.800		0.846	0.877	0.809	0.600	0.260
EC	0.909	0.881	0.903	0.846		0.980	0.978	0.857	0.576
PO	0.892	0.924	0.868	0.877	0.980		0.988	0.832	0.607
GDP	0.926	0.947	0.867	0.809	0.978	0.988		0.866	0.650
CUT	0.927	0.877	0.733	0.600	0.857	0.832	0.866		0.672
CUUSD	0.713	0.698	0.362	0.260	0.576	0.607	0.650	0.672	

Source: Elaborated by the author.

In Peru, total energy consumption directly increased in strong association with copper production, population, and GDP. The electrification of its economy correlated with this. Nevertheless, as in Bolivia, renewable levels of primary energy are not correlated with any variable (Table 4). As in Chile, copper prices do not correlate with any variable.

Table 5 | Pearson matrix for the Peruvian series

Peru	EA	EE	RPE	REWH	EC	PO	GDP	CUT	CUUSD
EA		0.873	-0.892	0.884	0.991	0.967	0.991	0.895	0.577
EE	0.873		-0.903	0.770	0.844	0.923	0.917	0.873	0.664
RPE	-0.892	-0.903		-0.643	-0.877	-0.859	-0.918	-0.748	-0.797
REWH	0.884	0.770	-0.643		0.886	0.934	0.876	0.942	0.301
EC	0.991	0.844	-0.877	0.886		0.963	0.986	0.895	0.565
PO	0.967	0.923	-0.859	0.934	0.963		0.980	0.956	0.568
GDP	0.991	0.917	-0.918	0.876	0.986	0.980		0.907	0.619
CUT	0.895	0.873	-0.748	0.942	0.895	0.956	0.907		0.437
CUUSD	0.577	0.664	-0.797	0.301	0.565	0.568	0.619	0.437	

Source: Elaborated by the author.

5 DISCUSSION – A GROUNDWORK FOR AN INTEGRAL ANALYSIS

This section looks for lessons learned from the previous sections and introduces new components to a critical analysis contrasting transition mineral production with the energy transition in LAC.

5.1 CONTROVERSIES FROM THE LATIN AMERICAN ENERGY TRANSITION

LAC countries (especially Bolivia and Peru, among those studied) could question the idea of a just sustainable energy transition. According to Figure 2, the shares of renewables in primary energy have decreased over time (1970-2019) in those countries. This contrasts with their increasing copper production and GDP. In other words, since the 2000s, economic growth and copper production have failed to correlate with a cleaner energy primary matrix (Tables 3 and 5). The NCRE (excluding hydropower) registered a smooth and limited rise in both countries since the 2000s, sharing approximately 6% of the generated electric power in 2020 (Figure 4). Although increasing GDP levels correlate with electricity access, universalizing access to electricity is still an unresolved task, questioning compliance with SDG 7. Moreover, regarding the analyzed qualitative information, Bolivia and Peru show intensive fossil fuel exploitation activity, which stimulated the emergence of several socio-ecological conflicts in critical localities.

It is worth noting that according to the IEA, the world share of electricity as an end-use is approximately 20%, and the world share of primary renewables is approximately 14% (IEA, 2022a, 2022b). Evaluating the Bolivian, Chilean, and Peruvian performances in both variables, Bolivia is under the global levels in both. On the other hand, Chile and Peru are over the global levels in both (Figure 9). Nevertheless, Peru has presented backtracking over the years in the share of renewables in primary energy. The question to further study is, why are Bolivia and Peru deploying fewer (proportionally) renewables? Is that sustainable? Is it equitable? If not, how can this tendency be broken?

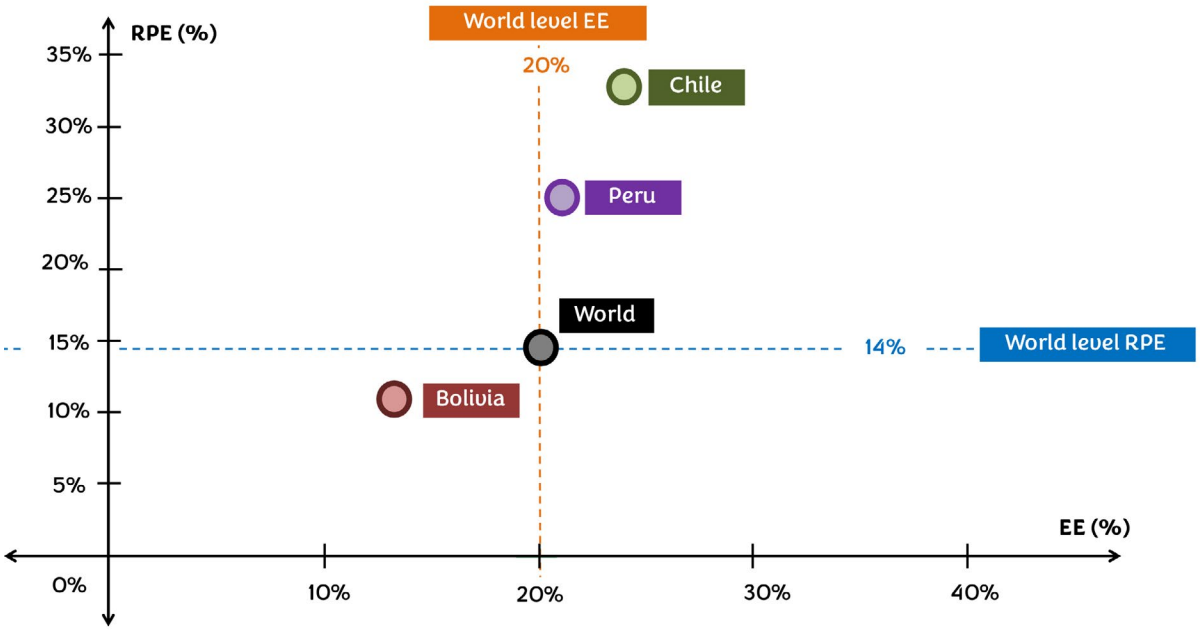

Figure 9 | Compared to world levels, renewable primary energy (RPE) and electrification of the economy (EE)

Source: Elaborated by the author.

Hydropower played a critical historical role in the studied countries because, at least until the 2000s (when NCREs were yet to spread), it constituted a significant part of the produced low-carbon power (see Figure 4). It is a critical issue in the middle of the debate on sustainable energy transition. The three

analyzed countries face socio-ecological conflicts associated with constructing these infrastructures. NCRE projects also have stimulated socio-ecological conflicts. Finally, fossil fuel imports (especially in Chile) might stimulate intricate socioeconomic scenarios and vulnerability due to the volatility of global energy prices.

Regarding copper exploitation, in the Chilean and Peruvian cases, the main task might be associated with the emergence of socio-ecological conflicts in the territory since both present more than twenty cases of environmental injustices related to copper activities. Looking at the EJAtlas data, socio-ecological conflicts seem inherent to copper exploitation since all South American Pacific coastal areas register associated disputes. What are the pending tasks of the copper sector with societies and the environment? The next item gives some clues to discuss this.

5.2 EXTRACTIVISM IN LAC – ECONOMY AND POLICY VIEWS

5.2.1 HISTORICAL TRENDS

The Latin American insertion into the global market in the 20th century and the beginning of the 21st century intensified its commodity activity. Nevertheless, this trend started some time ago, when Latin America became a peripheral supplier of low-processing materials to the Global North (CALDERÓN; PRIETO, 2020). In an exciting scientific debate, Jason Hickel recently pointed to the colonial dimensions of the ecological crisis, highlighting the excesses of the Global North via its large net appropriation of resources from the Global South (HICKEL; HALLEGATTE, 2022). Moreover, most spaces used for extractive activities correspond to rural areas inhabited by peasant and salaried populations, many of Indigenous origin (CALDERÓN; PRIETO, 2020).

Neoliberalism, as a hegemonic force dominating recent decades, has tended to change the socioeconomic valuation of shared spaces toward a capital-dependent path, more so if we consider the prevalent historical extractivism in the region (VERGARA-PERUCICH; BOANO, 2021). Svampa (2021) argued that, in the 21st century, extractivisms are the result of an accelerated increase in social metabolism within the framework of neoliberal capitalism with intensive consumption. This implies a greater pressure on commons, which are transformed into commodities, consequently aggravating the climate crisis and the destruction of local ecosystems.

5.2.2 UNEQUAL CONDITIONS

With extractive industries emerged the notion of unequal income distribution concerning spaces (or geography) and societal strata. Irarrazaval (2020) studied the Bolivian and Peruvian natural gas sectors, concluding that sometimes inequality is grounded in the local geography of class relations, marginalizing social groups in weaker political and economic positions. The Puchuncaví township in Chile has had both energy-intensive and polluting industries since at least 1967 and a marginal evolution in social equality compared with national levels (GAYO *et al*., 2022).

Since both mining and energy industries focus on specific areas due to the location of potentials or the location of resources, specific social sectors and ecosystems are particularly affected. With this, an uneven ecological distribution also emerged. Then, environmental and energy injustices are reproduced.

5.2.3 CONTEMPORARY POLICY DISCOURSES ABOUT CRITICAL RESOURCES

A new progressive political wave has recently emerged in LAC. Among its foremost voices, a contemporary discourse grew regarding transition minerals. Álvaro García Linera called for state control

over commodities (LINERA, 2022). At the same time, Maristella Svampa pointed to private and state corporations and their articulations to neglect public assets within the commodities consensus stage. Thus, an ecoterritorial stamp has dominated the new social collectives facing extractivism in recent years (SVAMPA, 2021).

We find a long-term unresolved ontological discussion about extractivism and development conceptions in LAC. Paradoxically, the emergence of an Indigenous president (Evo Morales, 2006-2019) in Bolivia showed a confrontation of different worldviews. On the one hand, the Bolivian plurinational state reinforced institutions to preserve its cultural and ecological heritage and reinforce the rights of nature. On the other hand, it recuperated the public control of national resource exploitation. Then, a wave of neo-extractivisms paid the price of social equity and progressive reforms (HOPE, 2022).

As lithium has emerged as a critical transition mineral, states might reinforce their pivotal management role. For instance, Mexico reformed its Mining Law, situating the state as the only entity authorized to explore, exploit, use, and benefit from lithium (ESTADOS UNIDOS MEXICANOS, 2022). Likewise, the Chilean president, Gabriel Boric, recently announced the creation of a national lithium company (BORIC, 2022). Since Morales' government, the Bolivian state has prioritized lithium-driven industrialization, fostering this sector and arranging several strategic joint partnerships with foreign companies (VOSKOBOYNIK; ANDREUCCI, 2022).

5.3 SOCIO-ECOLOGICAL ISSUES IN CONTRAST TO A "MODERN" PARADIGM

The ecological economy focuses on the environmental conditions limiting economic activity (CECHIN, 2010). Some researchers who have taken this approach offer some narratives that highlight issues related to the biophysical boundaries of Earth, its entropic death, and its system collapse triggered by unsustainable development or the current growth-oriented economy (CLEVELAND; RUTH, 1997; HICKEL; HALLEGATTE, 2022; MARQUES, 2022; MAX-NEEF, 2010).

Political ecology analyzes power relations and political conflicts over the environment. Consequently, it explores social struggles that have emerged since the appropriation of nature (LEFF, 2013). At the start of the 21st century, Enrique Leff stimulated the field to move further:

> The environmental crisis questions the ontological, epistemological and ethical premises on which modernity has been founded, denying the limiting laws and potentials of nature and culture; environmental degradation is the product of a globalizing and homogenizing societal paradigm that has denied the power of the heterogeneous and the value of diversity. (LEFF, 2000)

The ecological economy and political ecology are helpful tools to explore the relationships between the mining and energy sectors and society, the environment, and the economy, considering that we are facing an ecological crisis. As Meyer and Vilsmaier (2020) described, ontological, epistemological, and ethical foundations should be considered concerning the study of sustainable futures and the search for alternative theories of transformations in the human – nature coexistence.

5.3.1 CONFLICTS AND SACRIFICE ZONES

Earth is a single, complex, integrated system. Nevertheless, biophysical imbalances resulting from anthropogenic activity might be critical at different levels (STEFFEN *et al.*, 2015). The three analyzed countries showed localities agglutinating more than one intensively polluting company (for instance, mining, energy, and chemical companies). These are called sacrifice zones, and continuing risks from chronic environmental impacts on health and livelihoods and ongoing epistemic violence lead to social resistance (ANBLEYTH-EVANS *et al.*, 2022). Sacrifice zones check for unbalanced ecological distribution

since local populations and ecosystems shoulder disproportionate and unequal pollution burdens over time (GAYO et al., 2022).

For example, the neighbouring townships of Puchuncaví and Quintero in Chile have a total area of 448 km^2, with a population of ~50,500 people and concentrating more than 17 polluting companies, including thermoelectric plants, a refinery, and a copper smelter, which relate to hydrocarbon distribution, chemical storage, and gas distribution companies (ANBLEYTH-EVANS *et al.*, 2022; TAPIA-GATICA et al., 2020). Recently, the Chilean president, Gabriel Boric, expressed concern about them and announced the progressive end of operations of the copper smelter, attempting to reduce pollution in the zone after several critical health events in recent years (DIARIOUCHILE, 2022).

5.3.2 WATER: AN ESSENTIAL RESOURCE

Satoh *et al.* (2022) concluded that, due to climate change, even in a low-emission scenario, Andean South America (especially Chile) could experience an unprecedented critical drought in the upcoming years and decades. The surface areas of Andean lakes in central Chile tended to diminish during the 2010s. These declines coincided with decreasing precipitation and increasing regional temperatures (FUENTEALBA *et al.*, 2021). Recently, Cereceda-Balic *et al.* (2022) showed how open-pit copper mining influenced the reduction of a few Chilean Andean glaciers.

5.4 INTERSECTION POINTS – BETWEEN ENERGY TRANSITION, EARTH BOUNDARIES, AND A SOCIO-ECOLOGICAL CRISIS

Rockström *et al*. (2009) defined boundaries to the safe operating space for humanity concerning the Earth system and its biophysical subsystems or processes. Currently, based on the idea of a future "good life for all," Brand *et al*. (2021) proposed "societal boundaries" as a form to self-limit socio-ecological transformations and cope with the deepening ecological crisis and its devastating socioeconomic impacts. These limits pertain to poverty, inequality, ecological destruction, injustices, subordination, exploitation, consumption, and the defence of the commons, among others. Societal boundaries are structural issues set by political rules that secure material and energy conditions to guarantee a good life. They also involve relational, spiritual, and affective dimensions of well-being rooted in equity, solidarity, cooperation, participation, redistribution capability, and cohabitation of diverse modes of living.

5.5 A NEW GEOPOLITICAL CONFIGURATION

An exciting discussion emerges from the following questions: Where, how, by whom, for whom, and toward whom should mass and energy flow in energy transition times? In our intricate world context, geopolitics could contribute to resolving these questions as the field that studies the international scene, underlining power (un)balances, spatial relations, historical causation, and national interests (CAIRO CAROU, 1993; SLOAN; GRAY, 1999). It applies now more than ever. The world economy is experiencing dynamic shifts, and states are pivotal in reinforcing their control over strategic fields (such as mineral and energy sources) as power unbalances emerge, reconfiguring geographic and virtual frontiers and political structures.

A new global power configuration is growing since critical actors emerged in parallel with sustainable transitions. China, for example, became pivotal in the global and LAC scenarios. Calvo and Valero (2021) pointed out that China possesses essential mineral reserves to fabricate clean energy technology. Moreover, the Indo-Pacific region – led by China – has secured a pivotal position in the global supply of materials and components, which are critical if the world follows the net-zero 2050 path (IEA, 2022c).

Overall, 79.5% of Chilean copper rents came from Asia in 2020 (80.6% of its copper shipments), 55.1% of which came from China (SERNAGEOMIN, 2021).

After the Washington consensus, LAC suffered a strong wave of economic neo-liberalization and reprimarization. Meanwhile, the explosive economic growth of China demanded growing quantities of commodities from LAC (COONEY, 2016). Energy and mining extractive industries became pivotal. From 2009 to 2013, commodities comprised four of China's most significant LAC exports (ABDENUR, 2017). This could mean reproducing and reinforcing Theotonio dos Santos's dependence theory, which postulates that some countries expand their economies to become self-sustaining. In contrast, on the other side of the system, dependent countries could boost their economies depending on the pace of the former. Thus, following dos Santos, financial and technological dependence could be in force (SANTOS, 2011).

China also expanded its economic influence over LAC – with private and state capital – via mergers, acquisitions, joint ventures, and greenfield projects in critical economic sectors. Generally, extractive industries were associated with mergers and acquisitions. Chinalco (the Aluminum Corporation of China) is one such example, becoming the operator of one of the world's largest copper and molybdenum deposits, the Toromocho mine, in central Peru (ABDENUR, 2017).

6 FINAL CONSIDERATIONS

LAC cases evince Georgescu-Roegen's claim of mass and energy flows confronting nature's limits. Fossil fuel and critical mineral extractive activities (in both carbon-based and low-carbon eras) have threatened social structures, local livelihoods, and ecological balances over time. Additionally, LAC has a long-term historical economic configuration based on exploiting commodities, which has emerged since the instauration of the modern world-system paradigm (DELGADO, 2016; LEFF, 2013; MARTÍNEZ-ALIER, 2015; ULLOA, 2017). Currently, it seems that "green growth" narratives around energy transitions may be camouflaging an old (capital-based) way of responding to emerging, more complex contemporary challenges such as climate change (BROWN; SPIEGEL, 2019).

If we consider our just and equitable energy transition definition, Bolivia and Peru face critical challenges. LAC has suffered – and could continue to – the impacts of the complex global economic and ecological scenario. The region had a 7.7% GDP economic contraction in 2020. Moreover, poverty grew, showing the sensitivity of the population to economic growth (GROTTERA, 2022). With unmet human necessities, such as access to affordable, reliable, sustainable, and modern energy, it is imperative to go to new socioeconomic configurations that establish economic and ecological equity. As we described, guaranteeing a just energy transition and redefining the role of extractive industries within national economies is critical and requires political definitions, mainly in the Global South. We know that "natural resources" have a political dimension (HUBER, 2019), but we strongly perceive it within the complex current ecological crisis.

Nonrenewable resource exploitation and indiscriminate use have become shreds of evidence of the boundaries of Earth. Although Chilean socio-ecological conflicts are mainly associated with mining and Bolivia faces conflicts with fossil fuels, they are two sides of the same coin. They locally, subnationally, nationally, and regionally show unequal ecological distributions. As Martinez-Alier sentenced, "unfair ecological distribution is inherent to capitalism" (MARTÍNEZ-ALIER, 2020).

As Zografos and Robbins (2020) claimed, planning a sustainable future and transition and a green transformation has social and ecological costs that some people and territories must assume! In this case, sacrifice zones in the periphery of the global economy have shouldered it. Addressing sustainable transitions under the current socioeconomic model could reproduce green sacrifice zones arising from the transition from mineral exploitation.

In Hickel and Hallegatte (2022), Hickel hits the nail on the head when he says, "more growth means more energy demand, and rising energy demand will make it more challenging to decarbonize the economy in the short time we have left." Additionally, Hallegatte highlighted that the wealthiest countries and societal strata must stop reproducing unsustainable (energetically intensive) behaviour! The Chilean case illustrates wealth concentration as unresolved trouble despite greater per capita incomes. As Hickel (2019) reinforced, redistribution is pivotal, especially when countries reach an income that can satisfy their citizens' needs. Max-Neef (2010) suggested moving toward efficiency, sufficiency, and well-being.

Could it be possible to meet human priorities and environmental goals at the same time? Considering social and ecological justice and equity, the relevant questions are "What are the economic growth boundaries in the Global South?" and "How many times can the Global South depend on commodity exploitation?" Studying these issues in the Global South requires reviewing new dimensions. We suggest at least three: deconstruction, decolonization, and dependence.

DECLARATION OF CONFLICTING INTERESTS

The author declared no potential conflicts of interest concerning this study's research, authorship, and/or publication.

NOTES

1| For example, as this article is being written, Germany has stated that it will reactivate coal-fired plants to replace the lack of Russian gas (SEVILLANO, 2022).

2 | According to the International Renewable Energy Agency (IRENA, 2022), bioenergy, geothermal, hydropower, ocean, solar, and aeolian sources are examples of renewable energy. Nonconventional renewable energy sources (NCRE) generally include bioenergy, geothermal, ocean, solar, aeolian, and small hydropower plants. Sometimes, national definitions (considered in regulations and policies) vary due to interpretations regarding small hydropower plants. For instance, NCRE considers small hydropower plants in Chile those with a capacity below 20 MW (POQUE GONZÁLEZ, 2021)adopting an interdisciplinary perspective, the influence of Covid19 pandemic on the Chilean and Brazilian energy transition towards sustainability of 21st century. Subsequently, there are presented the main opportunities and challenges of social, environmental, and technical nature that might determine the development of the electricity systems of both countries after the current crisis will be overcome. The strong positive correlation between the Gross Domestic Product (GDP.

3 | The GINI indicator ranges from 0 to 1, in which values near 1 maximize inequality, and values near 0 tend to perfect equality.

4 | Placed on the Coquimbo Region cost, the Dominga project comprises two open pit mines for iron ore and copper extraction, a harbour to load the mineral, a desalination plant, and a processing plant (TEMPER; BENE; MARTINEZ-ALIER, 2015).

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¿Quién paga el precio? Controversias socioecológicas asociadas a la transición energética en Sudamérica

Quem paga o preço? Controvérsias socioecológicas associadas à transição energética na América do Sul

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ARTICLE- VARIA

RESUMEN

Las transformaciones vinculadas a la búsqueda de sistemas energéticos y económicos más sostenibles pueden tener costes sociales y ecológicos que algunas comunidades y territorios deben asumir. Pueden surgir controversias asociadas al desarrollo de nuevas cadenas productivas, por ejemplo, aquellas relativas a la actividad de los "minerales de la transición". Este estudio examina las relaciones entre la transición energética, la sociedad y el medio ambiente, centrándose en el cobre como mineral "high-tech" y considerando Bolivia, Chile y Perú, tres países con economías minero-dependientes. Así, se busca descifrar si los países se están tornando más renovables, eficientes y modernos, y si esto se correlaciona con la actividad industrial asociada al cobre y factores sociales a nivel país. Como resultado, Bolivia tiene tareas pendientes tanto en la demanda como en la producción de energía. A pesar del buen desempeño en materia de renovables y eficiencia, Chile y Perú tienen tareas pendientes relacionadas con la distribución ecológica ligada a los sectores minero y energético. Las economías basadas en la minería podrían poner de manifiesto la fragilidad de las transiciones verdes en lo que respecta a alcanzar los objetivos sostenibles, teniendo en cuenta la igualdad, la justicia y el cuidado de los ecosistemas.

Palabras clave: Transición energética. Extractivismo. Transiciones justas. Límites naturales. Limites sociales. América del Sur.

RESUMO

As transformações ligadas à busca por sistemas energéticos e econômicos mais sustentáveis poderiam trazer custos sociais e ecológicos que algumas comunidades e territórios devem suportar. Além disso, podem surgir controvérsias relacionadas com o desenvolvimento de novas cadeias de produção, por exemplo, a atividade industrial associada à exploração e produção dos minerais de transição. Este estudo examina as relações entre transição energética, sociedade e o meio ambiente, focando o cobre como mineral de alta tecnologia, e considerando como casos de estudo a Bolívia, o Chile e o Peru, três países com economias dependentes da mineração. Tenta-se explorar se os países estão se tornando mais renováveis, eficientes e modernos, e se isso está correlacionado com a produção de cobre e fatores sociais. Como resultado, a Bolívia tem pendências tanto na demanda quanto na produção de energia.

Apesar do bom desempenho histórico das energias renováveis e da eficiência energética, o Chile e o Peru têm questões a serem resolvidas relacionadas à distribuição ecológica, concernente aos setores de mineração e energia. As economias baseadas na mineração poderiam evidenciar a fragilidade das transições verdes para alcançar objetivos transversalmente sustentáveis, levando em conta a equidade, a justiça, e o cuidado com os ecossistemas.

Palavras-chave: Transição energética. Extrativismo. Transições justas. Limites naturais. Limites sociais. América do Sul.

1 INTRODUCCIÓN

La transición energética se ha convertido en un eje crítico dentro del proceso de descarbonización de las economías que busca afrontar y mitigar el cambio climático. En el lado de la producción de energía, las matrices han empezado a incluir fuentes cada vez más bajas en carbono para sustituir a los combustibles fósiles. Por otra parte, según el Grupo Intergubernamental de Expertos sobre el Cambio Climático (IPCC), la electricidad está aumentando su participación en la energía de uso final, en un proceso denominado "electrificación de la economía" (IPCC, 2022). Según la Agencia Internacional de la Energía (AIE), la electricidad de bajas emisiones y la electrificación de la economía son fundamentales para alcanzar un sistema global de emisiones netas cero (IEA, 2022a). Sin embargo, aquello implica el desarrollo de nuevas tecnologías y cadenas de producción. Las materias primas críticas para el desarrollo de estas tecnologías son denominadas metales "high-tech" o "minerales de transición" (VOSKOBOYNIK; ANDREUCCI, 2022). Calvo y Valero (2021) señalan 13 elementos prospectivamente críticos para el desarrollo de tecnología energética sostenible, ellos son: telurio (Te), plata (Ag), cadmio (Cd), cobalto (Co), cromo (Cr), cobre (Cu), galio (Ga), indio (In), litio (Li), manganeso (Mn), níquel (Ni), estaño (Sn) y zinc (Zn). En la actualidad, los países con mayor producción de estos minerales son la República Popular China (Zn, Te, Sn, In, Ga, Cd), Indonesia (Ni), Sudáfrica (Cr, Mn), Australia (Li), la República Democrática del Congo (Co), Chile (Cu) y México (Ag).

América Latina y el Caribe (ALC) desempeñan un papel medular en la transición energética global, puesto que, países como Chile y Perú son líderes mundiales en la producción de cobre. México lidera la producción de plata, y Bolivia, Argentina y Chile comparten una de las reservas de litio más extensas dentro del globo – el denominado "triángulo del litio". Por otro lado, Brasil y México siguen dependiendo económicamente de los hidrocarburos, y se encuentran entre los mayores productores a nivel mundial. No obstante, las industria energética y minera han estimulado históricamente conflictos socioecológicos, mientras que, las ganancias y los beneficios no han favorecido a todos por igual (BORDERA et al., 2022; POQUE GONZÁLEZ; SILVA; MACIA, 2022).

Los casos de la industria de la energía y minería en ALC exponen un paradigma elemental: ¡La naturaleza limita a la economía! Tal como advirtieron Meadows *et al*. (1972), existen necesidades humanas insatisfechas, mientras que, los recursos naturales no renovables – como los combustibles fósiles y los minerales – son finitos. Además, como afirma Nicholas Georgescu-Roegen, de acuerdo con la Segunda Ley de la Termodinámica, el crecimiento económico industrial, tal como se conoce actualmente, presupone un uso creciente de masa y/o energía. Luego, la actividad económica disemina residuos en el medio ambiente (Figura 1). Algunos (no todos) los materiales utilizados (insumos) pueden reciclarse (CECHIN, 2010), pero la energía no, puesto que esta se disipa (MARTINEZ-ALIER *et al*., 2016).

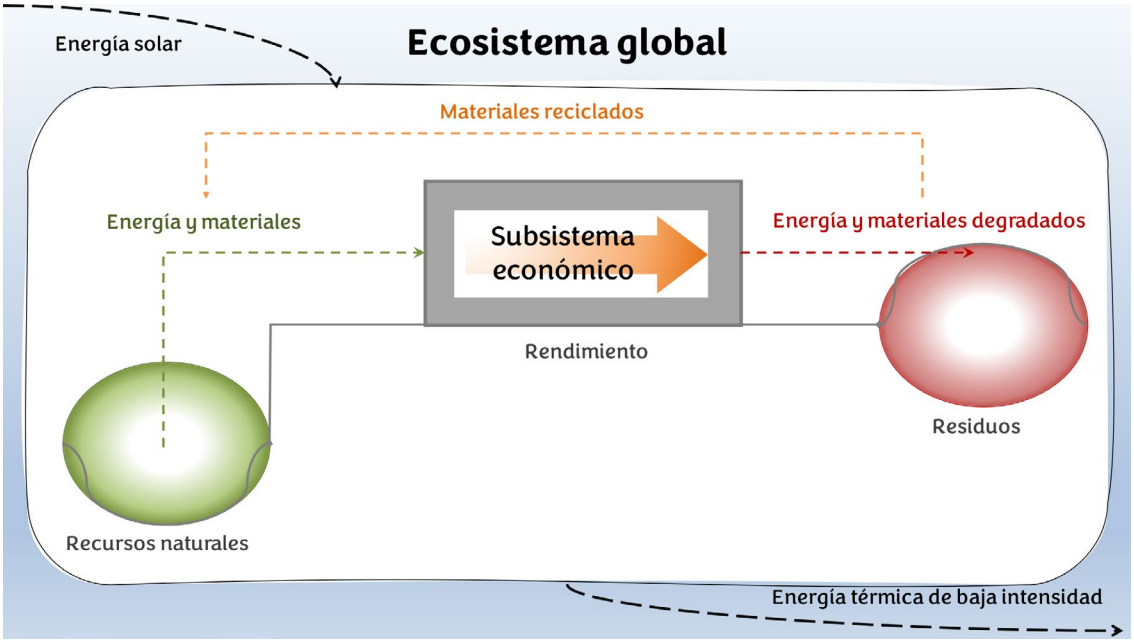

Figura 1 | Modelo económico de Nicholas Georgescu-Roegen

Fuente: Creado por el autor, basado en Cavalcanti (2012) y Cleveland & Ruth (1997).

En resumen, la actividad económica industrial global requiere – inevitablemente – de materia y/o energía, y como describe Max-Neef (2010), "la economía es un subsistema de un sistema mayor y finito, la biosfera" (Figura 1). Entonces, podríamos suponer que para llevarse a cabo, la transición energética necesita forzosamente de nuevos materiales. Luego, vale la pena cuestionarse sobre ¿cuál es la relación entre la transición energética, la sociedad, la economía y el medio ambiente? ¿Cuáles son las limitaciones naturales que perfilan las transiciones energéticas?

Dicho lo anterior, este estudio evalúa las relaciones y controversias entre la transición energética, la sociedad y el medio ambiente. Para explorar estas relaciones, se ha considerado al cobre, dada su condición de mineral de transición. Asimismo, el estudio se enfoca en algunos países productores de este mineral en ALC – Bolivia, Chile y Perú. La estructura del trabajo comprende la Sección 2, que se centra en la integración de conceptos clave; la Sección 3, que muestra la metodología utilizada; y la Sección 4, que expone nuestros principales resultados. Finalmente, la Sección 5 articula una discusión interdisciplinaria, mientras que, la Sección 6 concluye y estimula nuevas investigaciones sobre este tema.

2 CONTEXTUALIZACIÓN: LA CRISIS Y LAS FRONTERAS DEL MEDIO AMBIENTE

Los esfuerzos gubernamentales para afrontar y mitigar el cambio climático en las últimas tres décadas no han sido suficientes (DUNLAP, 2023)socio-ecological problems are nothing new. Despite all efforts to resolve environmental dilemmas, socio-ecological catastrophe has only intensified. Governments, in response, have unveiled the green economy to confront ecological and climate catastrophe. The green economy, however, has worsened socio-ecological conditions, invigorating the present trajectory of (techno. El IPCC afirma que el cumplimiento de los objetivos asociados al aumento de la temperatura media global fijados por el Acuerdo de París (1,5 -2°C) implica intensos esfuerzos hacia una economía de emisiones netas cero (IPCC, 2022). En 2022, teniendo en cuenta aquello que los gobiernos actualmente están haciendo para alcanzar las metas propuestas, la AIE (2022a) estima – con una probabilidad de ocurrencia del 50% – que el aumento de la temperatura media podría ser de aproximadamente 2,5°C en 2100.

La economía mundial sufrió recientemente los efectos de la pandemia del Covid-19, desencadenando un complejo contexto que alteró el comportamiento y causalidad entre los mercados financieros y de

materias primas. Posteriormente, en 2022, el conflicto entre Ucrania y la Federación Rusa estimuló una nueva etapa de incertidumbre y volatilidad en los mercados mundiales de materias primas, lo cual se superpuso a la crisis que ya estaba en marcha (ADEKOYA *et al.*, 2022; ALI *et al.*, 2022; BORDERA *et al.*, 2022; IGLESIAS; RIVERA-ALONSO, 2022). Para la AIE (2022a), "la crisis ha estimulado presiones inflacionistas y ha creado un riesgo inminente de recesión".

La desesperación por mejorar las condiciones socioeconómicas y superar las crisis financieras puede, a menudo, estimular la omisión de la existencia de los límites de la Naturaleza[1] (CAVALCANTI, 2012), principalmente en las economías dependientes de los commodities. Así, alentados por el intento de impulsar planes políticos de corto plazo hacia una recuperación económica acorde con el crecimiento económico industrial, los países podrían abandonar las vías de desarrollo de bajas emisiones de carbono, amenazando los límites biofísicos de la Tierra (AVIS, 2022). Como describe Martínez-Alier (2022), la economía industrial es entrópica y, por lo tanto, va hacia las fronteras de la extracción de materias primas y de la eliminación de residuos, provocando daños y conflictos. Recordemos que la energía se disipa; mientras tanto, sólo algunos materiales pueden ser reciclados (Figura 1).

2.1 UNA TRANSICIÓN ENERGÉTICA JUSTA Y LA DISTRIBUCIÓN ECOLÓGICA

“De la misma forma que abordar el cambio climático es un requisito previo para corregir la injusticia global, llevar a cabo una acción climática de forma equitativa y justa es un requisito previo para el éxito de la transición” (CRONIN *et al*., 2021). Según el IPCC, una transición justa garantizaría un conjunto de principios, procesos y prácticas para incluir a todas las personas, trabajadores, lugares, sectores, países o regiones en el vuelco de una economía de altas emisiones de carbono hacia otra de bajas emisiones. La protección social, la democracia, el diálogo, el bienestar, la equidad y la justicia son fundamentales. Luego, los procesos desarrollados en este contexto deben respetar a los grupos vulnerables y su dignidad (IPCC, 2022).

Ocasionalmente, la configuración de los sistemas energéticos y económicos suelen propagar las desigualdades e injusticias entre las sociedades. Por ejemplo, algunos países exportadores netos de combustible tienen altos niveles de pobreza energética (KNOX *et al*., 2022)a growing body of literature has started to examine the (in. Actualmente, entre 35 y 40 millones de personas en ALC carecen de acceso a servicios energéticos esenciales, como la electricidad y los combustibles modernos (GUZOWSKI; MARTIN; ZABALOY, 2021). Así, el concepto de justicia energética surgió como un marco para debatir cuestiones locales y globales de equidad entre las personas, en relación con el suministro, la producción y el consumo de energía (IWIŃSKA; LIS; MĄCZKA, 2021).

La justicia ambiental surge desde el debate sobre la distribución ecológica. Ella se refiere al reparto desigual de los costes y beneficios medioambientales potencialmente resultantes de la actividad económica. Además, apunta a las asimetrías sociales, espaciales y temporales en el uso de los recursos y servicios. Actualmente, este concepto se asocia a la disminución de los recursos naturales, la pérdida de biodiversidad, la contaminación, la escasez, la degradación y la búsqueda de un futuro sostenible (LEFF, 2013).

2.2 EXTRACTIVISMOS

Siguiendo a Gudynas (2017), el "extractivismo" es la explotación de recursos naturales en gran intensidad o volumen y la posterior exportación de al menos la mitad de los bienes extraídos a los mercados mundiales, como productos básicos o materias primas. Desde la década de 2000, la expresión "neoextractivismo" se ha vinculado a los gobiernos progresistas de ALC. En el neoextractivismo – también llamado extractivismo del siglo XXI, los Estados desempeñan un papel protagónico vinculado al fomento de la industria extractiva. La clase política argumentó la legitimidad de este rol a través

de la promoción de planes de desarrollo social progresivos, empleando los capitales obtenidos del extractivismo. No obstante, las actividades extractivas estimularon conflictos socioecológicos, evidenciando una distribución ecológica desigual dentro del continente (SVAMPA, 2021; VILLALBA-EGUILUZ; ETXANO, 2017).

2.3 UNA BREVE INTRODUCCIÓN A LA TRANSICIÓN ENERGÉTICA EN ALC

Según la Organización Latinoamericana de Energía (Olade), en 2020, el 36,3% de la electricidad de ALC fue producida vía combustibles fósiles. Además, el 20% de la energía de uso final de ALC procedía de la electricidad, mientras que el 50% provino del petróleo y sus derivados (OLADE, 2022b). Luego, subregiones como Centroamérica o el Caribe importan más del 70% del total del petróleo utilizado y sus derivados (OLADE, 2022a), lo que les hace vulnerables a la volatilidad de los mercados mundiales (GROTTERA, 2022).

Algunos países de ALC han transitado a las energías renovables no convencionales (ERNC)[2]. En 2005, Belice, Costa Rica, El Salvador, Guatemala y Nicaragua generaron más del 10% de su electricidad anual a partir de las fuentes solar, eólica, geotérmica y térmica renovable. En 2020, esta lista incluía también a Uruguay, Brasil, Chile, Honduras y México. Costa Rica y Uruguay prácticamente descarbonizaron la producción de electricidad, mientras que Paraguay depende casi por completo de la hidroelectricidad (POQUE GONZÁLEZ; SILVA; MACIA, 2022)tendencias y rupturas que experimenta\n\nel sector energético de América Latina y el Caribe (ALC.

2.4 LOS MINERALES DE LA TRANSICIÓN: EL CASO DEL COBRE

Según la AIE, la demanda de minerales de transición podría duplicarse o cuadruplicarse de aquí a 2030, debido a la creciente implementación de las energías renovables, los vehículos eléctricos, el almacenamiento en baterías y el desarrollo de nuevas redes eléctricas. Así, el uso del cobre podría aumentar significativamente en términos de volúmenes absolutos. La demanda actual, de aproximadamente 6 millones de toneladas métricas (t) al año, podría aumentar hasta 11 t y 16 t en 2030. Por otra parte, el reciclaje de los minerales de transición es actualmente infrautilizado, teniendo en cuenta que el 95% de la masa de los componentes de los paneles solares es reciclable, al igual que sucede con las turbinas eólicas (IEA, 2022a).

3 TEORÍA, MATERIALES Y MÉTODOS

Este estudio se centra en el cobre, teniendo en cuenta su papel prominente dentro de los minerales de transición críticos (CALVO; VALERO, 2021; IEA, 2022a). Además, contempla a los países andinos Bolivia, Chile y Perú, pues, tienen economías altamente dependientes de la minería (ERICSSON; LÖF, 2019) y con producción de cobre. A partir de estos casos, el estudio explora la relación entre la transición energética, el medio ambiente, la sociedad y la explotación del cobre. A continuación, se muestra algunas características de los países estudiados y, luego, se presenta el trayecto metodológico.

3.1 ESTUDIOS DE CASO

En 2020, Chile tenía las reservas de cobre más extensas del mundo, con 200 millones de toneladas, el 23% del total mundial, mientras que Perú tenía el 11% (CANADA, 2022). En cuanto a la energía, Bolivia tiene una economía relativamente ineficiente, ya que necesita más energía para producir una unidad de producto interno bruto (PIB). Bolivia también posee una baja proporción de electricidad como energía de uso final. La Tabla 1 presenta brevemente los países estudiados.

Tabla 1 | Perfiles nacionales

Parámetro	*Bolivia*	*Chile*	*Perú*
2020 PIB per cápita (USD a precios constantes de 2015)	2.986,0	12.890,3	5.807,1
2020 PIB del sector minería (% del PIB nacional)	7,1	6,1	3,9
2019 suministro renovable de energía primaria (% del total)	11,2	33,8	25,1
2019 intensidad energética a	1,65	0,74	0,73
2020 electrificación de la economía (% – proporción de la electricidad en la energía de uso final)	12,0	22,0	20,9
2020 acceso a la electricidad (% – proporción de la población)	93,7	99,7	97,0
2018 gases de efecto invernadero per cápita (tCO2e per cápita)	5,0	5,9	3,0

a | Consumo final de energía (en miles de barriles equivalentes de petróleo) /PIB en millones de dólares (a precios constantes de 2010).

Fuente: Datos de Olade (2022a), United Nations (2021) y World Bank (2022).

3.2 METODOLOGÍA

Este estudio explora las tendencias hacia sistemas energéticos bajos en carbono, contrastándolas con las amenazas sociales, ecológicas y los conflictos socioambientales asociados a los sectores de la energía y la minería del cobre. El comportamiento y las relaciones de cada país a lo largo del tiempo se evaluó mediante cuatro etapas cualitativas y cuantitativas, a saber:

i. Para analizar comparativamente las mudanzas en el uso de las fuentes y el consumo energéticos, se utilizaron tres series de datos, a saber, la proporción de energía primaria renovable (1970-2019), la proporción de electricidad como energía de uso final (1970-2020) y la proporción de fuentes renovables para generar electricidad (2000-2020). La información empleada proviene de UN (2021) y de Olade (2022a). Esta etapa explora cuan renovables y eficientes (o no) se tornan los países a lo largo del tiempo. La proporción de renovables en toda la energía de que dispone cada país a cada año muestra si los combustibles fósiles están desapareciendo. La proporción de electricidad en toda la energía de uso final cada año es una prueba de que los países están participando en el proceso global de electrificación de las economías. Por último, la introducción de las ERNC en la generación de electricidad desde la década de 2000 revela si los países son más modernos, limpios y eficientes.

ii. Luego, la evaluación socioeconómica contrasta los indicadores de la actividad minera del cobre con las condiciones sociales nacionales. Se considera la producción de cobre (1990-2020), el precio del cobre (1990-2020) y el PIB per cápita nacional (1970-2020). Esta etapa consideró información documentada en bases de datos nacionales (como información pública ministerial) y mundiales (como el Banco Mundial). El objetivo principal de esta etapa es explorar los beneficios de la minería en las economías y sociedades de los países estudiados.

iii. Posteriormente, una evaluación cualitativa explora la relación entre los sectores de la energía y la minería del cobre, el medio ambiente y la sociedad a partir del surgimiento de conflictos socioecológicos documentados en el Atlas de Justicia Ambiental (EJAtlas) (MARTÍNEZ-ALIER, 2020; TEMPER; BENE; MARTINEZ-ALIER, 2015). El principal objetivo de esta fase es trazar y comprender las dimensiones socioecológicas de la minería del cobre y el desarrollo del sector energético en los países estudiados.

iv. Finalmente, la información mostrada en las tres etapas anteriores fue cruzada, buscando interrelaciones a través de correlaciones de Pearson entre la transición energética, las variables sociales y la actividad minera del cobre dentro de la ventana temporal del siglo XXI

(2000-2019). Nueve variables describen el comportamiento de estos campos de estudio, a lo largo del tiempo y en cada país (Tabla 2). El coeficiente de correlación de Pearson busca correspondencias, contradicciones o controversias en Bolivia, Chile y Perú respecto a la relación entre la transformación de las fuentes de energía, los atributos socioeconómicos y la producción de cobre. Para cada país se elabora una matriz que contiene los coeficientes de Pearson para cada relación entre variables.

Tenga en cuenta que el coeficiente de correlación de Pearson asume un valor entre -1 y 1, en el que 0 se refiere a la ausencia de correlación, 1 es una correlación totalmente positiva y -1 es una correlación totalmente negativa. Además, un valor de correlación de 0,7 entre dos variables indicaría una relación significativa y positiva entre ellas. Una correlación positiva significa que a medida que la variable A aumenta, también lo hará la variable B, mientras que si el valor de la correlación es negativo, B disminuirá a medida que lo haga A (NETTLETON, 2014). Luego, a partir de las nueve variables seleccionadas (Tabla 2), este trabajo explora si, desde la década de 2000, los países se están volviendo más renovables, limpios, modernos y eficientes, y si esto se correlaciona con el crecimiento de la población, los ingresos nacionales, la producción de cobre o los precios del cobre.

Este trabajo utiliza principalmente datos de tipo secundarios, los que están debidamente referenciados. En consecuencia, no hay compromisos ni transgresiones éticas de ningún tipo.

Tabla 2 | Series de datos

Variable		*Código*	*Unidad*	*Fuente*
Acceso a la electricidad		EA	% de la población	Olade (2022a)
Electrificación de la economía		EE	% de la energía de uso final	Olade (2022a)
Energía primaria renovable		RPE	% de la energía	UN (2021)
Electricidad renovable [a]		REWH	% de la electricidad	Olade (2022a)
Consumo final de energía		EC	1012 cal	Olade (2022a)
Población		PO	Miles de personas	UN (2021)
PIB		GDP	USD constantes de 2015	World Bank (2022)
Producción de cobre	Bolivia	CUT	Toneladas métricas	INE (2022)
	Chile			Cochilco (2022)
	Perú			Ministerio de Energía y Minas (2022)
Precio del cobre [b]		CUUSD	USD por libra	Macrotrends (2022)

a| Sin hidroelectricidad. b| precio de cierre de fin de año.

Fuente: Elaborada por el autor.

4 EN LA TRÍADA ENERGÍA-SOCIEDAD-MEDIO AMBIENTE EN BOLIVIA, CHILE Y PERÚ

4.1 ¿QUÉ ACONTECE CON LAS FUENTES DE ENERGÍA?

La Figura 2 muestra que la energía primaria en Bolivia y Perú tendió a aumentar su proporción de fuentes no renovables. Sólo 11 de cada 100 unidades de energía primaria en Bolivia provinieron de fuentes renovables en 2019; mientras tanto, Chile mantuvo una matriz mixta a lo largo del tiempo. Según el balance energético de 2020, Bolivia exporta aproximadamente el 74% de su producción de gas natural. Chile importa el 98% de su petróleo, el 80% de su gas natural y el 89% de su carbón mineral. Perú es un caso intermedio, ya que exporta el 31% del gas natural producido mientras que importa el

28% de su petróleo y el 62% de su carbón (OLADE, 2022a). En otras palabras, Chile es muy vulnerable a los mercados internacionales de combustibles fósiles.

En cuanto a la electrificación de sus economías, Chile y Perú aumentaron la electricidad como energía de uso final entre 1970 y 2020 (Figura 3). Aunque Bolivia muestra una tendencia suave a aumentar la electricidad como uso final, sólo 12 de cada 100 unidades de energía que consume provienen de la electricidad en 2020. Hay que tener en cuenta que el mundo se encuentra hoy en un 20% aproximadamente, y si las tendencias actuales se mantienen, podría aumentar al 22% en 2030 y al 28% en 2050 (IEA, 2022a). En resumen, Bolivia necesita mejoras tecnológicas en el lado de la demanda.

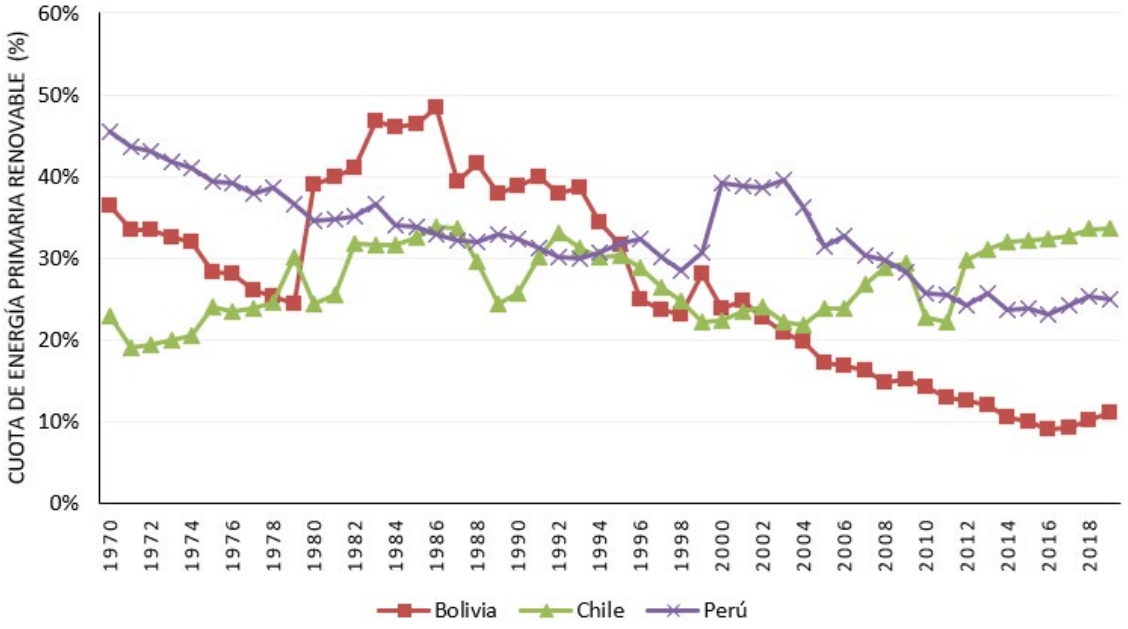

Figura 2 | Cuota de energía primaria renovable (1970-2019)

Fuente: UN (2021).

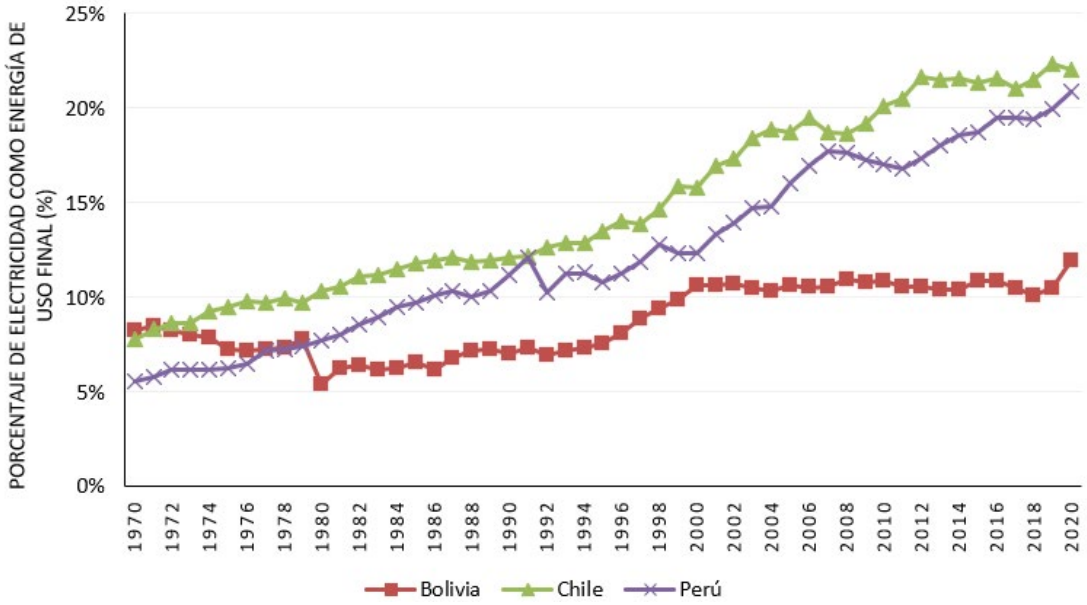

Figura 3 | Porcentaje de electricidad como energía de uso final (1970-2020)

Fuente: Olade (2022a).

La generación eléctrica introdujo las ERNC durante el siglo XXI (Figura 4). Si consideramos la hidroelectricidad (serie de color intenso en la Figura 4), durante el siglo XXI, Chile ha mantenido aproximadamente el 50% de su generación eléctrica asociada a fuentes renovables. Sin embargo, Bolivia y Perú redujeron su cuota de producción de energía renovable a lo largo del tiempo, alcanzando el 64% y el 35% en 2020, en contraste con el 81% y el 54% que ostentaban en el 2000, respectivamente. Si prescindimos de la hidroelectricidad – considerando sólo las fuentes solar, eólica, geotérmica y de biomasa, apenas Chile avanzó notoriamente en esta transición, alcanzando el 22% de su cuota de electricidad producida en 2020 por vía de estas fuentes (Figura 4). Bolivia y Perú sólo generaron aproximadamente un 6% a partir de las fuentes solar, eólica, geotérmica y de biomasa (OLADE, 2022a). Tanto en Bolivia como en Perú la introducción de las ERNC es aún tarea pendiente.

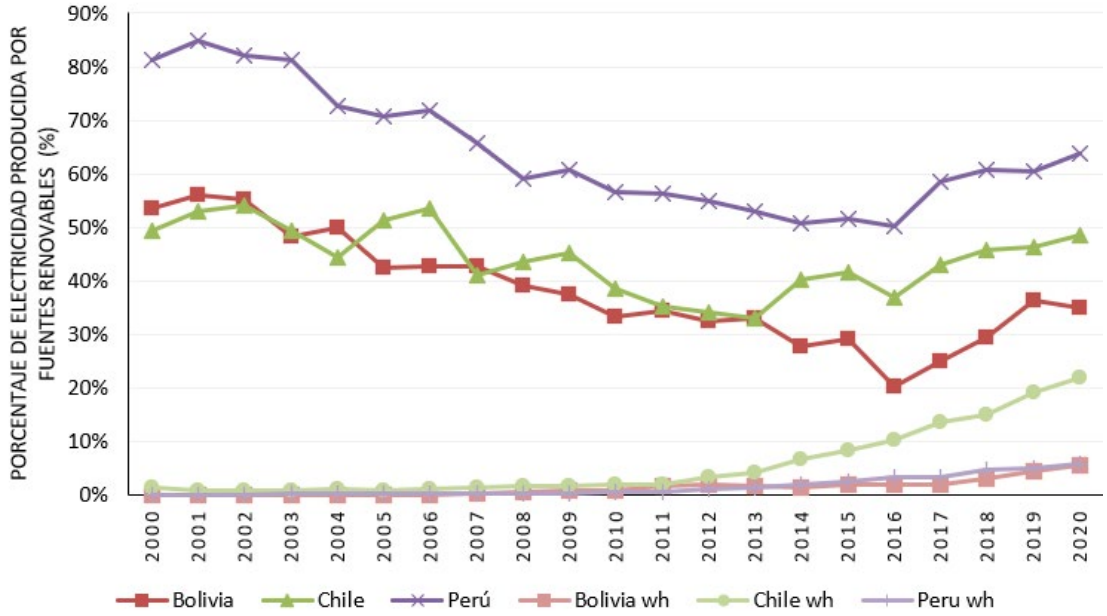

Figura 4 | Proporción de la producción anual de energía por fuentes renovables (2000-2020)

Nota: Para distinguir la importancia de la hidroelectricidad, las series de color fuerte consideran la hidroelectricidad, la termoelectricidad renovable y las fuentes solar, eólica y geotérmica. Las series de color claro (con la marca "wh" = sin hidro) muestran los datos que ignoran la hidroelectricidad.

Fuente: Olade (2022a).

4.2 ACERCA DE LAS CUESTIONES SOCIOECONÓMICAS

La producción de cobre ha sido un factor fundamental en las economías andinas sudamericanas. La Figura 5 muestra que Chile y Perú aumentaron drásticamente su producción de cobre entre la década de 1990 y 2020 (COCHILCO, 2022; MINISTERIO DE ENERGÍA Y MINAS, 2022). Según el Instituto Nacional de Estadística (INE), Bolivia superó las 2.000 toneladas métricas de cobre producidas en la década de 2010 (INE, 2022). Los precios internacionales del cobre subieron en la década de 2000 (MACROTRENDS, 2022). De acuerdo con el Banco Mundial (2022), entre 2006 y 2011, más del 10% del PIB chileno y peruano provino de la minería. En 2020, Chile y Perú tenían la primera y segunda mayor producción de cobre del mundo, mientras que China ocupaba la tercera posición, con un 28,5%, 10,9% y 8,4%, respectivamente. En 2020, el 50% de las exportaciones chilenas fueron de cobre, lo cual representó el 85,5% de todas las exportaciones mineras chilenas (SERNAGEOMIN, 2021).

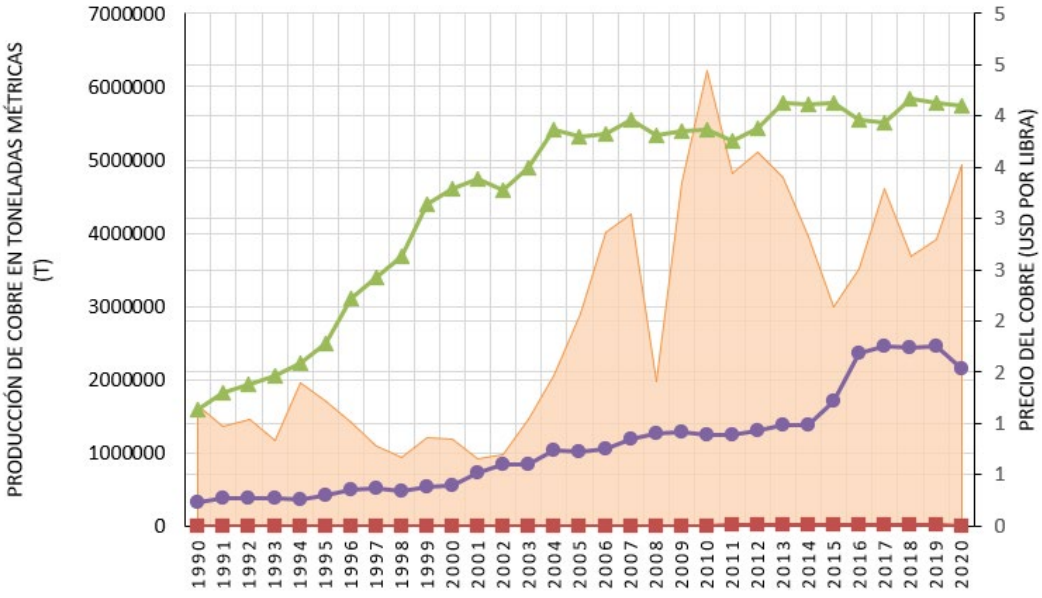

Figura 5 | Producción de cobre (en toneladas métricas) por país y precio (en USD por libra)

Nota: En naranja: precio del cobre. En rojo: Producción de cobre en Bolivia. En verde: Producción de cobre en Chile. En lila: Producción de cobre en Perú.

Fuente: Cochilco (2022); INE (2022); Macrotrends (2022); and, Ministerio de Energía y Minas (2022).

A pesar del aumento a largo plazo del PIB per cápita a lo largo del tiempo (Figura 6), los tres países se enfrentan a problemas de equidad y pobreza. En 2020, el indicador de GINI chileno[3] fue de 0,475, por encima de la media latinoamericana (0,464), mostrando en consecuencia, una tarea pendiente con relación a la distribución de la riqueza. Por el contrario, Bolivia pasó de 0,635 en 2000 a 0,449 en 2020, mostrando una evolución en este ámbito. En 2020, el indicador GINI peruano fue de 0,464. En 2020, Bolivia, Chile y Perú tenían un 32,3%, 14,2% y 28,4% de su población en situación de pobreza, respectivamente; el promedio latinoamericano era del 33% (UN, 2021). Si tenemos en cuenta los Objetivos de Desarrollo Sostenible (ODS), Bolivia y Perú se enfrentan a retos en relación con el ODS 7 – garantizar el acceso a una energía asequible, fiable, sostenible y moderna para todos – ya que, una parte considerable de su población carece de acceso a la electricidad (Tabla 1) (OLADE, 2022a; POQUE GONZÁLEZ; SILVA; MACIA, 2022). Esto revela la falta de justicia energética en esos países, pues son exportadores de combustibles fósiles

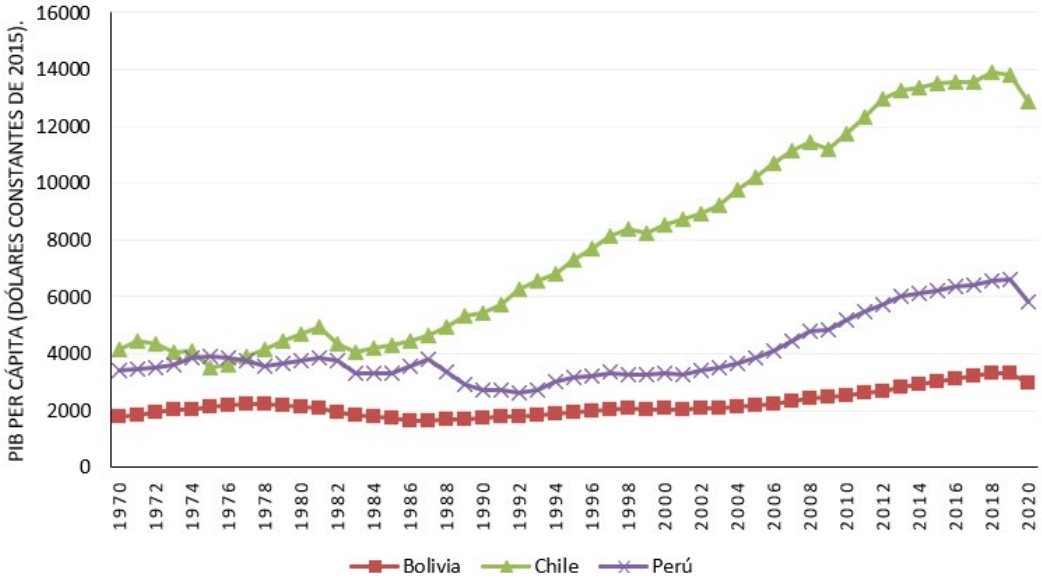

Figura 6 | PIB per cápita (USD constantes de 2015)

Fuente: World Bank (2022).

4.3 CUESTIONES SOCIOECOLÓGICAS

Según el EJAtlas, la minería del cobre está históricamente asociada al surgimiento de conflictos socioecológicos en la Sudamérica andina – Figura 7 muestra una concentración de casos conflictivos en la región. Bolivia tiene tres conflictos asociados a la actividad cuprífera surgidos en la década de 2010, mientras que, Perú presenta 29 casos, algunos de ellos de larga data. Además, ambos países se enfrentan a problemas relacionados con la extracción de plata, oro y litio. Chile presenta 21 casos conflictivos relacionados con la minería del cobre, especialmente en la zona norte.

En Chile, las empresas privadas suelen participar en los conflictos socioecológicos en torno al cobre. Sin embargo, proyectos como Dominga[4] se asociaron a casos de corrupción, en los que los agentes de la administración pública ignoraron impactos ambientales. Como cuestiones transversales en los tres países, los pueblos indígenas, los campesinos y los agricultores son los principales grupos que se resisten a los proyectos mineros. Además, el agua es un recurso esencial directa o indirectamente disputado que opone los intereses de las empresas versus las necesidades humanas, el patrimonio social, cultural y ecológico y a la preservación de los ecosistemas. En Chile, la figura privada de los derechos de agua, establecida por el Código de Aguas de 1981, se tornó un factor político que estimuló la emergencia de nuevos conflictos (BUDDS, 2004).

Figura 7 | Conflictos socioecológicos en torno al cobre

Nota: Los colores identifican el principal tipo de conflicto registrado en el EJAtlas. Así, el naranja es: extracción de minerales y materiales de construcción; el cian es: gestión del agua; el rojo es: conflictos industriales y de servicios públicos; el marrón claro es: gestión de residuos.

Fuente: Temper; Bene y Martinez-Alier (2015).

Además de las disputas asociadas a la minería del cobre, Bolivia y Perú también se enfrentan a conflictos socioecológicos relacionados con la extracción y el procesamiento de gas natural y petróleo. Por su parte, Chile presenta principalmente conflictos asociados a las industrias de generación renovable y no renovable (Figura 8). En cuanto a la actividad de los combustibles fósiles, Bolivia posee nueve proyectos controvertidos de petróleo y gas natural, mientras que Perú mostró 11 episodios agudos y conflictos asociados a esta industria. Además, la población local se ha enfrentado a dos proyectos hidroeléctricos en Bolivia y a ocho en Perú.

En cuanto a la explotación de combustibles fósiles, el sur de Chile ha mostrado tres proyectos polémicos de minería de carbón. En cuanto a la generación de electricidad, el EJAtlas informó sobre cuatro proyectos controvertidos relacionados con termoelectricidad en el centro y el norte de Chile. Además, la población chilena se ha enfrentado a 16 proyectos hidroeléctricos en la región sur. En cuanto a las ERNC, un proyecto geotérmico y dos plantas de producción de energía eólica han desencadenado conflictos socioecológicos dentro del país.

Figura 8 | Conflictos socioecológicos desencadenados por proyectos energéticos

Nota: Los colores identifican el principal tipo de conflicto registrado en el EJAtlas. Así, el naranja es: extracción de minerales y materiales de construcción; el cian es: gestión del agua; el rojo es: conflictos industriales y de servicios públicos; el marrón claro es: gestión de residuos; el amarillo es: nuclear; el negro es: combustibles fósiles y justicia climática/energética; el gris es: infraestructuras y entorno construido; el verde es: conflictos de biodiversidad y conservación; y, el marrón oscuro es: conflictos de biomasa y tierra.

Fuente: Temper; Bene y Martinez-Alier (2015).

4.4 CONTRASTANDO

Empleando la correlación de Pearson, este punto explora las interrelaciones entre la transición energética, las variables sociales y la actividad minera del cobre durante el siglo XXI. En Bolivia, el consumo total de energía aumentó en asociación directa con su población, el PIB y la producción de cobre. Además, el acceso a la electricidad y la introducción de las ERNC en la generación de electricidad

están positivamente correlacionados. Como ya se ha dicho, la electrificación de la economía y la cuota de energía primaria renovable son tareas pendientes, ya que no están correlacionadas con la evolución de la economía, el consumo de energía y la demografía. La cuota de renovables en la energía primaria está correlacionada negativamente con todas las variables excepto con la electrificación. La electrificación no está correlacionada con ninguna variable (Tabla 3).

Tabla 3 | Matriz de Pearson para las series bolivianas

Bolivia	*EA*	*EE*	*RPE*	*REWH*	*EC*	*PO*	*GDP*	*CUT*	*CUUSD*
EA		-0,186	-0,936	0,916	0,996	0,992	0,990	0,806	0,623
EE	-0,186		0,108	-0,283	-0,237	-0,215	-0,238	-0,166	-0,123
RPE	-0,936	0,108		-0,769	-0,934	-0,956	-0,914	-0,806	-0,713
REWH	0,916	-0,283	-0,769		0,915	0,907	0,926	0,659	0,461
EC	0,996	-0,237	-0,934	0,915		0,993	0,996	0,823	0,595
PO	0,992	-0,215	-0,956	0,907	0,993		0,988	0,796	0,637
GDP	0,990	-0,238	-0,914	0,926	0,996	0,988		0,798	0,542
CUT	0,806	-0,166	-0,806	0,659	0,823	0,796	0,798		0,461
CUUSD	0,623	-0,123	-0,713	0,461	0,595	0,637	0,541	0,461	

Fuente: Elaborada por el autor.

En Chile, el consumo total de energía está directamente correlacionado con todas las variables. Luego, con el precio del cobre tiene una correlación suave. El precio del cobre no tiene una correlación fuerte con ninguna variable. La correlación más fuerte se da entre el consumo total de energía, la población y el PIB (Tabla 4).

Tabla 4 | Matriz de Pearson para las series chilenas

Chile	*EA*	*EE*	*RPE*	*REWH*	*EC*	*PO*	*GDP*	*CUT*	*CUUSD*
EA		0,922	0,763	0,627	0,909	0,892	0,926	0,927	0,713
EE	0,922		0,756	0,697	0,881	0,924	0,947	0,877	0,698
RPE	0,763	0,756		0,800	0,903	0,868	0,867	0,733	0,362
REWH	0,627	0,697	0,800		0,846	0,877	0,809	0,600	0,260
EC	0,909	0,881	0,903	0,846		0,980	0,978	0,857	0,576
PO	0,892	0,924	0,868	0,877	0,980		0,988	0,832	0,607
GDP	0,926	0,947	0,867	0,809	0,978	0,988		0,866	0,650
CUT	0,927	0,877	0,733	0,600	0,857	0,832	0,866		0,672
CUUSD	0,713	0,698	0,362	0,260	0,576	0,607	0,650	0,672	

Fuente: Elaborada por el autor.

En Perú, el consumo total de energía aumentó en fuerte correlación con la producción de cobre, la población y el PIB. La electrificación de la economía también está correlacionada con ellos. Sin embargo, al igual que en Bolivia, los niveles de energía primaria renovable no están correlacionados con ninguna variable (Tabla 4). Al igual que en Chile, los precios del cobre no tienen correlación fuerte con ninguna variable.

Tabla 5 | Matriz de Pearson para las series peruanas

Perú	EA	EE	RPE	REWH	EC	PO	GDP	CUT	CUUSD
EA		0,873	-0,892	0,884	0,991	0,967	0,991	0,895	0,577
EE	0,873		-0,903	0,770	0,844	0,923	0,917	0,873	0,664
RPE	-0,892	-0,903		-0,643	-0,877	-0,859	-0,918	-0,748	-0,797
REWH	0,884	0,770	-0,643		0,886	0,934	0,876	0,942	0,301
EC	0,991	0,844	-0,877	0,886		0,963	0,986	0,895	0,565
PO	0,967	0,923	-0,859	0,934	0,963		0,980	0,956	0,568
GDP	0,991	0,917	-0,918	0,876	0,986	0,980		0,907	0,619
CUT	0,895	0,873	-0,748	0,942	0,895	0,956	0,907		0,437
CUUSD	0,577	0,664	-0,797	0,301	0,565	0,568	0,619	0,437	

Fuente: Elaborada por el autor.

5 DISCUSIÓN: UNA BASE PARA UN ANÁLISIS INTEGRAL

Esta sección explora las lecciones aprendidas a partir de las secciones anteriores e introduce nuevos componentes en un análisis crítico que contrasta la producción de minerales de transición con la propia transición energética en ALC.

5.1 CONTROVERSIAS DE LA TRANSICIÓN ENERGÉTICA LATINOAMERICANA

Los países de ALC – especialmente Bolivia y Perú, entre los estudiados – podrían cuestionar la idea de una transición energética justa. Según la Figura 2, en estos países la participación de las fuentes renovables en la energía primaria ha disminuido a lo largo del tiempo (1970-2019). Esto contrasta con el aumento de la producción de cobre y su PIB. En otras palabras, desde la década de 2000, el crecimiento económico y la producción de cobre no se han correlacionado con una matriz energética primaria más limpia (Tablas 3 y 5). Las ERNC – excluyendo la energía hidroeléctrica – registraron un aumento suave y limitado en ambos países, desde la década de 2000, comprendiendo aproximadamente el 6% de la energía eléctrica generada en 2020 (Figura 4). Aunque el aumento de los niveles del PIB se correlaciona con el acceso a la electricidad, la universalización del acceso a este bien sigue siendo una tarea pendiente, cuestionando el cumplimiento del ODS 7. Por otra parte, en relación con la información cualitativa analizada, Bolivia y Perú muestran una intensa actividad de explotación de combustibles fósiles, lo que estimuló el surgimiento de varios conflictos socioecológicos en localidades críticas.

Cabe señalar que, según la AIE, la cuota mundial de electricidad como uso final es de aproximadamente el 20%, y la cuota mundial de energías primarias renovables es de aproximadamente del 14% del total (IEA, 2022a, 2022b). Evaluando los números de Bolivia, Chile y Perú en ambas variables, Bolivia está por debajo de los niveles globales en ambas. Por otro lado, Chile y Perú están por encima de los niveles globales en los dos ítems (Figura 9). Sin embargo, Perú ha presentado un retroceso a lo largo de los años en la participación de las renovables en la energía primaria. La cuestión que vale la pena estudiar más a fondo es, ¿por qué Bolivia y Perú están desplegando menos energías renovables (proporcionalmente)? ¿Es eso sostenible? ¿Es equitativo? Si no lo es, ¿cómo se puede romper esta tendencia?

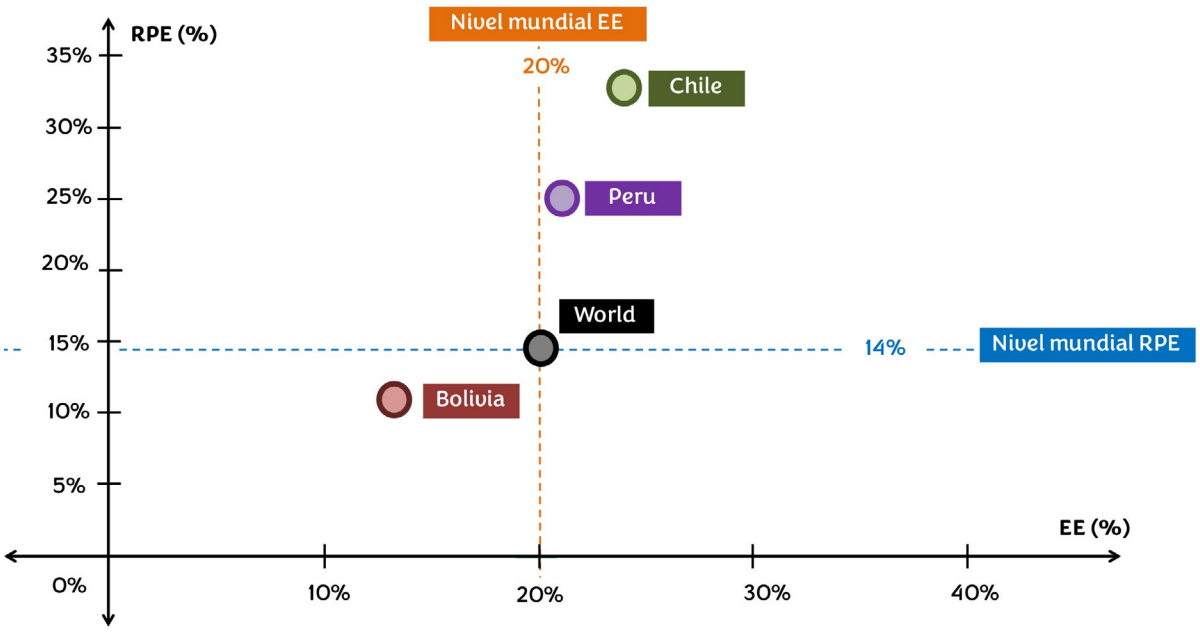

Figura 9 | En comparación con los niveles mundiales, la energía primaria renovable (EPR) y la electrificación de la economía (EE)

Fuente: Elaborada por el autor.

La energía hidroeléctrica desempeñó un papel histórico y fundamental en los países estudiados porque, al menos hasta la década de 2000 – cuando las ERNC aún no se habían propagado, constituía una parte importante de la energía producida con bajas emisiones de carbono (véase Figura 4). Ello apunta a una cuestión crítica en medio del debate sobre la transición energética. Los tres países analizados se enfrentan a conflictos socioecológicos asociados a la construcción de estas infraestructuras y la disputa por el agua. Luego, los proyectos de ERNC también han estimulado conflictos socioecológicos. Finalmente, las importaciones de combustibles fósiles – especialmente en Chile – podrían estimular intrincados escenarios socioeconómicos y de vulnerabilidad debido a la volatilidad de los precios globales de la energía.

En cuanto a la explotación del cobre, en los casos chileno y peruano, la principal tarea podría estar asociada al surgimiento de conflictos socioecológicos en el territorio, ya que ambos presentan más de veinte casos de injusticias ambientales relacionadas con esta industria. Observando los datos del EJAtlas, los conflictos socioecológicos parecen inherentes a la explotación del cobre, ya que todas las zonas costeras del Pacífico sudamericano registran disputas asociadas en este sentido. ¿Cuáles son las tareas pendientes del sector del cobre con las sociedades y el medio ambiente? El siguiente punto da algunas pistas para discutir aquello.

5.2 EL EXTRACTIVISMO EN ALC: VISIÓN ECONÓMICA Y POLÍTICA

5.2.1 TENDENCIAS HISTÓRICAS

La inserción de América Latina en el mercado global en el siglo XX y principios del XXI intensificó la actividad de los commodities. Así, América Latina se convirtió en proveedor periférico de materiales de bajo valor agregado para el Norte Global (CALDERÓN; PRIETO, 2020). En un apasionante debate científico, Jason Hickel apuntó recientemente a las dimensiones coloniales de la crisis ecológica, destacando los excesos del Norte Global a través de la apropiación neta de recursos del Sur Global (HICKEL; HALLEGATTE, 2022). La mayoría de los espacios utilizados para las actividades extractivas

corresponden a zonas rurales habitadas por poblaciones campesinas y asalariadas, muchas de ellas de origen indígena (CALDERÓN; PRIETO, 2020).

El neoliberalismo, como fuerza hegemónica dominante en las últimas décadas, ha tendido a cambiar la valoración socioeconómica de los espacios compartidos hacia una trayectoria dependiente del capital, más aún si consideramos el extractivismo histórico prevaleciente en la región (VERGARA-PERUCICH; BOANO, 2021). Svampa (2021) sostiene que, en el siglo XXI, los extractivismos son el resultado de un aumento acelerado del metabolismo social, en el marco del capitalismo neoliberal de consumo intensivo. Esto implica una mayor presión sobre los bienes comunes, los que se transforman en mercancías, agravando la crisis climática y la destrucción de los ecosistemas locales.

5.2.2 CONDICIONES DESIGUALES

Junto con las industrias extractivas surgió la noción de distribución desigual de la renta en relación con los espacios (o la geografía) y los estratos sociales. Irarrazaval (2020) estudió los sectores del gas natural boliviano y peruano, concluyendo que a veces la desigualdad se basa en la geografía local de las relaciones de clase, marginando a los grupos sociales en posiciones políticas y económicas más débiles. La comuna de Puchuncaví, en Chile, cuenta con industrias intensivas en el consumo de energía y contaminantes desde, al menos, el año 1967, sosteniendo una evolución marginal de la igualdad social en comparación con los niveles nacionales (GAYO *et al*., 2022).

Dado que tanto la industria minera como la energética se centran en zonas específicas debido a la ubicación de los potenciales o la localización de los recursos, determinados sectores sociales y ecosistemas se ven especialmente afectados. Con ello, también surge una distribución ecológica desigual. Entonces, las injusticias ambientales y energéticas tienden a reproducirse.

5.2.3 DISCURSOS POLÍTICOS CONTEMPORÁNEOS ACERCA DE LOS RECURSOS CRÍTICOS

Recientemente ha surgido una nueva ola progresista en ALC. Entre sus voces más destacadas creció un discurso contemporáneo sobre los minerales de transición. Álvaro García Linera abogó por el control estatal de las materias primas (LINERA, 2022). Al mismo tiempo, Maristella Svampa apuntó a las corporaciones privadas y estatales, y sus articulaciones, como actores determinantes en el descuido de los bienes públicos, en el marco de lo que ella denomina Consenso de los Commodities. Así, en los últimos años, una impronta ecoterritorial ha dominado los nuevos colectivos sociales frente al extractivismo (SVAMPA, 2021).

Encontramos una discusión ontológica no resuelta de largo plazo en torno al extractivismo y las concepciones del desarrollo en ALC. Paradójicamente, la emergencia de un presidente indígena (Evo Morales, 2006-2019) en Bolivia mostró una confrontación de cosmovisiones diversas. Por un lado, el Estado Plurinacional boliviano reforzó las instituciones para preservar su patrimonio cultural y ecológico, y, además, reforzar los derechos de la Naturaleza. Por otro lado, recuperó el control público de la explotación de los recursos nacionales no renovables. Luego, una ola de neoextractivismos pagó el precio de avanzar en la equidad social y las reformas progresistas (HOPE, 2022).

Dado que el litio ha surgido como un mineral de transición crítico, los Estados podrían reforzar su papel en la gestión de estos. Por ejemplo, México reformó su Ley Minera, situando al Estado como la única entidad autorizada para explorar, explotar, utilizar y beneficiarse del litio (ESTADOS UNIDOS MEXICANOS, 2022). Asimismo, el presidente chileno, Gabriel Boric, anunció recientemente la creación de una empresa nacional del litio (BORIC, 2022). A partir del gobierno de Morales, el Estado boliviano ha dado prioridad a la industrialización del litio, fomentando este sector y concertando varias asociaciones estratégicas con empresas extranjeras (VOSKOBOYNIK; ANDREUCCI, 2022).

5.3 CUESTIONES SOCIOECOLÓGICAS EN CONTRASTE CON UN PARADIGMA "MODERNO"

La economía ecológica se centra en las condiciones ambientales que limitan la actividad económica (CECHIN, 2010). Algunos investigadores que han adoptado este enfoque ofrecen narrativas que ponen de manifiesto cuestiones relacionadas con los límites biofísicos de la Tierra, su muerte entrópica y el colapso desencadenado por el desarrollo insostenible o la actual economía orientada al crecimiento (CLEVELAND; RUTH, 1997; HICKEL; HALLEGATTE, 2022; MARQUES, 2022; MAX-NEEF, 2010).

La ecología política analiza las relaciones de poder y los conflictos políticos en torno al medio ambiente. En consecuencia, explora las luchas sociales que han surgido desde la apropiación de la naturaleza (LEFF, 2013). A principios del siglo XXI, Enrique Leff señaló:

> La crisis ambiental cuestiona las premisas ontológicas, epistemológicas y éticas sobre las que se ha fundado la modernidad, negando las leyes limitantes y las potencialidades de la naturaleza y la cultura; la degradación ambiental es el producto de un paradigma social globalizador y homogeneizador que ha negado el poder de lo heterogéneo y el valor de la diversidad. (LEFF, 2000)

Tanto la economía ecológica como la ecología política son herramientas útiles para explorar las relaciones entre los sectores minero y energético y la sociedad, el medio ambiente y la economía, teniendo en cuenta que nos enfrentamos a una crisis ecológica. Como describieron Meyer y Vilsmaier (2020), deben considerarse los fundamentos ontológicos, epistemológicos y éticos en relación con el estudio de los futuros sostenibles y la búsqueda de teorías alternativas hacia las transformaciones que garanticen una armónica coexistencia hombre-naturaleza.

5.3.1 CONFLICTOS Y ZONAS DE SACRIFICIO

La Tierra es un sistema único, complejo e integrado. Sin embargo, los desequilibrios biofísicos resultantes de la actividad antropogénica podrían ser críticos en diferentes niveles (STEFFEN *et al.*, 2015). En los tres países analizados se observan localidades que aglutinan más de una empresa intensamente contaminante – por ejemplo, empresas mineras, energéticas y químicas. Estas se denominan zonas de sacrificio, y los continuos riesgos derivados de los impactos ambientales crónicos sobre la salud y los modos de vida, así como la violencia epistémica, conducen a la resistencia social (ANBLEYTH-EVANS *et al.*, 2022). Las zonas de sacrificio manifiestan una distribución ecológica desequilibrada, ya que las poblaciones y los ecosistemas locales soportan cargas de contaminación desproporcionadas y desiguales que perduran a lo largo del tiempo (GAYO *et al.*, 2022).

Por ejemplo, las comunas vecinas de Puchuncaví y Quintero, en Chile, tienen una superficie total de 448 km^2, con una población de ~50.500 personas, y concentran más de 17 empresas contaminantes, entre las que se encuentran centrales termoeléctricas, una refinería y una fundición de cobre, empresas de distribución de hidrocarburos, almacenamiento de productos químicos y distribución de gas (ANBLEYTH-EVANS *et al.*, 2022; TAPIA-GATICA *et al.*, 2020). Recientemente, el presidente chileno, Gabriel Boric, expresó su preocupación por la localidad y anunció el cese progresivo de las operaciones de la fundición de cobre, intentando reducir la contaminación en la zona, tras varios sucesos sanitarios críticos acaeciendo en los últimos años (DIARIOUCHILE, 2022).

5.3.2 AGUA: UN RECURSO ESENCIAL

Satoh *et al.* (2022) concluyó que, debido al cambio climático, incluso en un escenario de bajas emisiones, la Sudamérica andina – especialmente Chile – podría experimentar una sequía crítica sin precedentes en los próximos años y décadas. La superficie de los lagos andinos en la zona central de

Chile tendió a disminuir durante la década de 2010. Estos descensos coincidieron con la disminución de las precipitaciones y el aumento de las temperaturas regionales (FUENTEALBA *et al.*, 2021). Recientemente, Cereceda-Balic *et al.* (2022) mostró cómo la minería del cobre a cielo abierto influyó en la reducción de algunos glaciares andinos chilenos.

5.4 PUNTOS DE INTERSECCIÓN: ENTRE LA TRANSICIÓN ENERGÉTICA, LOS LÍMITES DE LA TIERRA Y LA CRISIS SOCIOECOLÓGICA

Rockström *et al*. (2009) definieron los límites del espacio operativo seguro para la humanidad en relación con el sistema Tierra y sus subsistemas o procesos biofísicos. En la actualidad, comenzando desde la idea de una futura " vida buena para todos", Brand *et al*. (2021) propuso los "límites sociales" como forma de limitar las transformaciones socioecológicas y hacer frente a la creciente crisis ecológica y a sus devastadores impactos socioeconómicos. Estos límites se refieren a la pobreza, la desigualdad, la destrucción ecológica, las injusticias, la subordinación, la explotación, el consumo y la defensa de los bienes comunes, entre otros. Los límites de la sociedad son cuestiones estructurales establecidas por reglas políticas que aseguran las condiciones materiales y energéticas para garantizar el buen vivir. También implican dimensiones relacionales, espirituales y afectivas del bienestar enraizadas en la equidad, la solidaridad, la cooperación, la participación, la capacidad de redistribución y la cohabitación de diversos modos de vida.

5.5 UNA NUEVA CONFIGURACIÓN GEOPOLÍTICA

Un apasionante debate surge a partir de las siguientes preguntas: ¿cómo, por quién, para quién y hacia quién deben fluir las materias y la energía en tiempos de transición energética? En nuestro intrincado contexto mundial, la geopolítica podría contribuir a resolver estas cuestiones, siendo aquel campo que estudia la escena internacional, subrayando los (des)equilibrios de poder, las relaciones espaciales, la causalidad histórica y los intereses nacionales (CAIRO CAROU, 1993; SLOAN; GRAY, 1999). Esto aplica ahora más que nunca. La economía mundial está experimentando cambios dinámicos, y los Estados son fundamentales para reforzar su control sobre campos estratégicos – como las fuentes de minerales y energía – a medida que surgen desequilibrios de poder, reconfigurando las fronteras geográficas, virtuales y las estructuras políticas.

Una nueva configuración de poder global está creciendo desde que surgieron actores críticos en paralelo a las transiciones sostenibles. China, por ejemplo, se convirtió en un pivote en el escenario global y en el de ALC. Calvo and Valero (2021) señalaron que China posee reservas minerales esenciales para fabricar tecnología de energía limpia. Además, la región del Indo-Pacífico – liderada por China – ha asegurado una posición fundamental en el suministro global de materiales y componentes, que son críticos si el mundo sigue la senda de cero emisiones netas en 2050 (IEA, 2022c). En total, el 79,5% de las rentas del cobre chileno procedieron de Asia en 2020 (el 80,6% de sus envíos de cobre), el 55,1% de las cuales procedieron de China (SERNAGEOMIN, 2021).

Después del Consenso de Washington, ALC sufrió una fuerte ola de neoliberalización y reprimarización económica. Mientras tanto, el explosivo crecimiento económico de China demandaba cantidades crecientes de commodities desde ALC (COONEY, 2016). Las industrias extractivas de la energía y la minería se convirtieron en un elemento fundamental. Entre 2009 y 2013, los commodities constituyeron cuatro de las cinco exportaciones más importantes de ALC a China (ABDENUR, 2017). Esto podría significar la reproducción de la teoría de la dependencia de Theotonio dos Santos, que postula que algunos países amplían sus economías para ser autosuficientes. Por el contrario, en el otro lado del sistema, los países dependientes podrían impulsar sus economías en función del ritmo de los primeros. Así, siguiendo a dos Santos, la dependencia financiera y tecnológica podría continuar vigente en ALC (SANTOS, 2011).

China amplió su influencia económica en ALC – con capital privado y estatal – a través de fusiones, adquisiciones, empresas conjuntas y proyectos totalmente nuevos en sectores económicos críticos. Por lo general, las industrias extractivas se asociaron a las fusiones y adquisiciones. Chinalco (Corporación de Aluminio de China) es un ejemplo de ello, al convertirse en el operador de uno de los mayores yacimientos de cobre y molibdeno del mundo, la mina de Toromocho, en Perú (ABDENUR, 2017).

6 CONSIDERACIONES FINALES

Los casos estudiados de ALC ponen de manifiesto la afirmación de Georgescu-Roegen de que los flujos de masa y energía se enfrentan a los límites de la Naturaleza. Las actividades de extracción de combustibles fósiles y minerales críticos – tanto en tiempos de altas emisiones de carbono como en la era del bajo carbono – han amenazado las estructuras sociales, los modos de vida locales y los equilibrios ecológicos a lo largo del tiempo. Además, ALC tiene una configuración económica históricamente basada en la explotación de materias primas, la que ha surgido desde la instauración del paradigma del sistema mundial moderno (DELGADO, 2016; LEFF, 2013; MARTÍNEZ-ALIER, 2015; ULLOA, 2017). Actualmente, parece que las narrativas de "crecimiento verde" en torno a las transiciones energéticas pueden estar camuflando una vieja forma – basada en el capital – de responder a los nuevos y más complejos desafíos contemporáneos, como el cambio climático (BROWN; SPIEGEL, 2019).

Si tenemos en cuenta nuestra definición de transición energética justa y equitativa, Bolivia y Perú se enfrentan a grandes retos. ALC ha sufrido – y podría seguir sufriendo – los impactos del complejo escenario económico y ecológico mundial. La región tuvo una contracción económica del 7,7% del PIB en 2020. Además, la pobreza creció, mostrando la sensibilidad de la población al crecimiento económico (GROTTERA, 2022). Con necesidades humanas insatisfechas, como el acceso a una energía asequible, fiable, sostenible y moderna, es imperativo transitar hacia nuevas configuraciones socioeconómicas que establezcan la equidad económica y ecológica. Como hemos descrito, garantizar una transición energética justa y redefinir el papel de las industrias extractivas dentro de las economías nacionales es fundamental y requiere definiciones políticas, principalmente en el Sur Global. Sabemos que los recursos naturales tienen una dimensión política (HUBER, 2019), pero lo percibimos con aún mayor intensidad dentro de la compleja crisis ecológica actual.

La explotación de los recursos no renovables y su uso indiscriminado se han convertido en una evidencia de los límites de la Tierra. Aunque los conflictos socioecológicos chilenos están asociados principalmente a la minería y los bolivianos a los combustibles fósiles, estas son dos caras de la misma moneda. A nivel local, subnacional, nacional y regional, ellos muestran distribuciones ecológicas desiguales. Como sentenció Martínez-Alier, "la injusta distribución ecológica es inherente al capitalismo" (MARTÍNEZ-ALIER, 2020).

Como apuntaron Zografos y Robbins (2020), la idea de planificar un futuro y una transición sostenibles y una transformación verde tiene costes sociales y ecológicos que algunas personas y territorios deben asumir. En este caso, las zonas de sacrificio de la periferia de la economía mundial lo han asumido. Abordar las transiciones sostenibles en el marco del actual modelo socioeconómico podría reproducir las zonas de sacrificio verdes, derivadas de la explotación de los minerales de la transición.

En Hickel and Hallegatte (2022), Hickel da en el clavo cuando dice que "más crecimiento significa más demanda de energía, y el aumento de la demanda de energía hará más difícil descarbonizar la economía en el poco tiempo que nos queda". Además, Hallegatte destacó que los países y estratos sociales más ricos deben dejar de reproducir comportamientos insostenibles – energéticamente intensivos. El caso chileno ilustra la concentración de la riqueza como un problema no resuelto a pesar de los mayores ingresos per cápita. Como Hickel (2019) reforzó, la redistribución es fundamental, especialmente cuando los países alcanzan una renta que puede satisfacer las necesidades de sus ciudadanos. Max-Neef (2010) sugirió avanzar hacia la eficiencia, la suficiencia y el bienestar.

¿Sería posible satisfacer las necesidades humanas primordiales y los objetivos medioambientales al mismo tiempo? Teniendo en cuenta la justicia y la equidad social y ecológica, preguntas pertinentes son: "¿Cuáles son los límites del crecimiento económico en el Sur Global?" y "¿Cuánto puede el Sur Global depender de la explotación de las materias primas?" Estudiar estas cuestiones en el Sur Global requiere revisar nuevas dimensiones. Sugerimos al menos tres: deconstrucción, descolonización y dependencia.

DECLARACIÓN DE CONFLICTOS DE INTERÉS

El autor declaró no tener ningún conflicto de intereses en relación con la investigación, la autoría y/o la publicación de este estudio.

NOTAS

1 | Por ejemplo, en el momento de escribir este artículo, Alemania ha declarado que reactivará las centrales de carbón para suplir la falta de gas ruso (SEVILLANO, 2022).

2 | De acuerdo con la Agencia Internacional de Energías Renovables (IRENA, 2022), la bioenergía, la geotermia, la energía hidráulica, el océano, la energía solar y las fuentes eólicas son ejemplos de energías renovables. Las fuentes de energía renovable no convencionales (ERNC) suelen incluir la bioenergía, la geotermia, el océano, la energía solar, la eólica y las pequeñas centrales hidroeléctricas. A veces, las definiciones nacionales (consideradas en las normativas y políticas) varían debido a las interpretaciones relativas a las pequeñas centrales hidroeléctricas. Por ejemplo, en Chile, la definición de ERNC considera a las pequeñas centrales hidroeléctricas que tienen una capacidad inferior a 20 MW (POQUE GONZÁLEZ, 2021) adopting an interdisciplinary perspective, the influence of Covid19 pandemic on the Chilean and Brazilian energy transition towards sustainability of 21st century. Subsequently, there are presented the main opportunities and challenges of social, environmental, and technical nature that might determine the development of the electricity systems of both countries after the current crisis will be overcome. The strong positive correlation between the Gross Domestic Product (GDP.

3 | El indicador GINI oscila entre 0 y 1, en el que los valores cercanos a 1 tienden a maximizar la desigualdad y los valores cercanos a 0 tienden a la igualdad perfecta.

4 | Situado en la costa de la Región de Coquimbo, el proyecto Dominga comprende dos minas a cielo abierto para la extracción de mineral de hierro y cobre, un puerto para cargar el mineral, una planta desalinizadora y una planta de procesamiento (TEMPER; BENE; MARTINEZ-ALIER, 2015).

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Impact of the transport system on air quality: the case of Rio de Janeiro, Brazil

Impacto do sistema de transporte na qualidade do ar: o caso do Rio de Janeiro, Brasil

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ABSTRACT

In the downtown area of Rio de Janeiro, Brazil, an urban mobility plan was implemented between 2011 and 2016 due to the 2014 Fifa World Cup and the 2016 Olympic Games. This study aimed to evaluate the environmental benefits achieved by this urban mobility plan by comparing two periods: 2013 (before the megaevents) and 2017 (after the megaevents). Energy consumption and emissions from buses were estimated, and regulated pollutants (O_3, CO, PM_{10}, and $PM_{2.5}$) were monitored. According to the calculations, NOx was the most emitted pollutant (62% of the total 20 tons). A 25% reduction in

levels for all pollutants was observed in 2017 compared to 2013. The reorganization of traffic shortened the bus routes, resulting in less fuel consumption (8%) and emissions. The annual mean concentrations of air pollutants (PM_{10}, $PM_{2.5}$, and CO) also decreased, improving air quality. However, the levels of O_3 increased, possibly owing to the reduction of NO_x levels.

Keywords: Air quality. Urban mobility. Light-rail transit. Pollutant emissions.

RESUMO

No centro da cidade do Rio de Janeiro, Brasil, foi implementado um plano de mobilidade urbana entre 2011 e 2016 devido à Copa do Mundo Fifa 2014 e aos Jogos Olímpicos 2016. Este estudo teve como objetivo avaliar os benefícios ambientais alcançados por esse plano de mobilidade urbana comparando dois períodos: 2013 (antes dos megaeventos) e 2017 (depois dos megaeventos). O consumo de energia e as emissões dos ônibus foram estimados e os poluentes regulamentados (O_3, CO, PM_{10} e $PM_{2,5}$) foram monitorados. De acordo com os cálculos, o NO_x foi o poluente mais emitido (62% do total de 20 t). Observou-se em 2017 uma redução de 25% de todos os poluentes em relação a 2013. A reorganização do tráfego encurtou as rotas de ônibus, resultando em menor consumo de combustível (8%) e emissões. As concentrações médias anuais de poluentes atmosféricos (PM_{10}, $PM_{2,5}$ e CO) também diminuíram, melhorando assim a qualidade do ar. No entanto, os níveis de O_3 aumentaram, possivelmente devido à redução dos níveis de NOx.

Palavras-chave: Qualidade do ar. Mobilidade urbana. Trânsito ferroviário leve. Emissões poluentes.

1 INTRODUCTION

Numerous studies were carried out in the metropolitan region of Rio de Janeiro (MRRJ) before, during and after the 2014 Fifa World Cup and the 2016 Olympic Games to assess air quality (*e.g.*, DE LA CRUZ *et al.*, 2019; GOMES *et al.*, 2018, JUSTO et al., 2020; VENTURA *et al.*, 2019a, b). However, the relationship between air quality, urban mobility, and fuel use has not been examined. Motor vehicles release various pollutants that are detrimental to people and the environment, primarily due to fossil fuel combustion (GUO *et al.*, 2013; LI *et al.*, 2011; VENTURA *et al.*, 2020; WANG *et al.*, 2010). In this context, this study aimed to investigate how the mobility management strategies implemented probably affected the air quality in Rio de Janeiro's downtown. The principal focus was on greenhouse gases (GHGs: carbon dioxide [CO_2] and methane [CH_4]) and regulated air pollutants (nitrogen oxides [NO_x], carbon monoxide [CO], particulate matter [PM_{10} and $PM_{2.5}$] and tropospheric ozone [O_3]), which are primarily caused by bus emissions. The most appropriate way to assess this impact is through monitoring the air quality of areas mostly impacted by this modal and also through estimates of energy consumption and pollutant emission scenarios due to the burning of fuels on the roads of the study region. Bus energy consumption and emissions were assessed in two scenarios: before (2013) and after (2017) the aforementioned megaevents, with regulated pollutants being tracked from 2013 to 2017.

It is important to emphasize that vehicles are the primary atmospheric pollutants in Rio de Janeiro, especially in the downtown area (INEA, 2016a, b). Therefore, appropriate traffic management solutions can help to reduce emissions and avoid traffic bottlenecks, lowering energy consumption. These solutions can also mitigate atmospheric gas (CO2, CH4, CO, NOx) and particles with aerodynamic diameter less than 10µm and 2.5µm (PM10 and PM2.5) emissions, enhancing social well-being. Fine particles (PM2.5) and certain gases (O3, NO2) are the principal pollutants of global concern for respiratory and cardiovascular disorders (GUO *et al.*, 2013; LI *et al.*, 2011; WANG *et al.*, 2010). Since there are few monitoring stations in Brazil, there is limited research on urban mobility and air quality. But Rio de Janeiro has the oldest and, currently, the second-largest air quality monitoring network in Brazil (GIODA *et al.*, 2016). As a result, the findings presented in this study are unprecedented and were achieved in collaboration with the government's environmental monitoring agency.

1.1 URBAN MOBILITY IN RIO DE JANEIRO

More than 80% of the Brazilian population lives in urban areas. Therefore, mobility is a critical issue to be considered by governments. Rio de Janeiro's uniqueness lies in the large urban area with a fast-rising population, which necessitates innovative urban mobility solutions for a variety of modes of transportation, including automobiles, buses, light-rail vehicles (LRVs), trams, trains, subways, ferries, and bicycles (ALMEIDA *et al.*, 2017; IZAGA, 2014; LINDAU *et al.*, 2016; MALHEIROS *et al.*, 2017). About 53% of the population uses public transportation, which provides appropriate transportation solutions. However, to travel the same distance, a ride on public transport takes roughly 40 min longer than driving (SETRERJ, 2003). Improvements in public transportation networks can result in more sustainable urban mobility and improved quality of life. Between 2011 and 2016, the MRRJ underwent structural improvements to host the 2014 Fifa World Cup and the 2016 Olympic Games (GATO; SALAZAR, 2018; SANTOS NETO *et al.*, 2018, VENTURA *et al.*, 2019a). Several areas of Rio de Janeiro's downtown were restored, including the port sector (Porto Maravilha), which covers 5 km² (Rio de Janeiro, 2009). The regeneration was foreshadowed in the region's municipal mobility plan, which includes restoring the urban infrastructure, the environment, and the region's historical and cultural assets (GOMES *et al.*, 2018; PORTO MARAVILHA, 2021). The Perimetral road was replaced by an expressway connecting downtown to the airport and major roads via a new urban tunnel (Marcelo Alencar's tunnel), which is the world's largest. Furthermore, a new road (Via Binário do Porto) was built to connect to a new tunnel (Rio 450 tunnel) (GATO; SALAZAR, 2018; PORTO MARAVILHA, 2021; SANTOS NETO *et al.*, 2018). The region's automobile circulation was improved due to these changes (Table 1).

Table 1 | Interventions implemented in the municipal urban mobility plan for the downtown area of Rio de Janeiro

Interventions	*Civil work period*	*Extension (km)*	*Lanes/ direction*	*Benefits*
Perimetral viaduct's demolition	November 2013 to April 2014	1.1 and 0.3	4	To amplify the vehicle circulation and revitalize the Port region
Expressway Via's construction	May 2014 to June 2016	1.6	3	To receive up to 110 thousand vehicles per day
Marcelo Alencar's tunne construction	October 2012 to June 2016	3.4	3	
Via Binário do Porto road's construction	September 2011 to November 2013	3.5	3	To receive up to 110 thousand vehicles per day
Rio450 tunnel's construction	October 2011 to March 2015	1.5	3*	To receive up to 55 thousand vehicles per day
Light-rail vehicles (LRVs)'s implementation	June 2016	24	-	Transport 300 thousand people per day
Providência Cable car terminal	July 2011 to July 2014	0.7	-	Offer mobility to almost 5,000 residents of the Morro da Providência community
Bike paths	February 2014 to June 20161	17	-	To offer the use possibility of this clean modal transport in this region

Note: *only one direction

Source: Porto Maravilha, 2021; ¹ Veja-Rio, 2017

Additionally, LRVs integrate all modes of downtown transportation, including ferries, cableways, and cruise ships. In addition, two smaller lines were constructed: line 2 (1.8 km) and line 3 (1.8 km) (PORTO MARAVILHA, 2021; VLT RIO, 2019). In this area, 32 LRVs traverse 28 km on a trail network with intervals ranging from 3 to 15 min with stop stations every 400 m. LRVs emit no pollutants into the atmosphere. In the downtown area, automobile and bus lanes have been replaced with LRVs and Bus Rapid Service (BRS) lines, which only allow buses and taxis to travel (ALMEIDA *et al*., 2017; SMTR, 2016), along with

the installation of bike paths (ALMEIDA *et al*., 2017; SMTR, 2016). Based on these considerations, assessing the impact of changes in urban mobility on air quality is essential to know whether the measures taken are effective.

2 MATERIALS AND METHODS

This study aimed to understand how the urban mobility strategy established to host the megaevents affected air quality in Rio de Janeiro's downtown. Two periods were considered: i) 2013: the year before the megaevents, when various mobility improvements were still being implemented; ii) 2017: the year following the megaevents, when the transportation system upgrades were completed. Vehicle emissions (2.1), energy usage (2.2), and air quality monitoring were the three primary metrics utilized to analyze the environmental consequences caused by automobiles over these periods (2.3). Based on the distance travelled, vehicle and energy usages were calculated. Unfortunately, only data for buses was available and only for the years 2013 and 2017. In contrast, air pollutant levels were monitored continuously from 2013 to 2017.

2.1 VEHICLE EMISSION ESTIMATES

The Traffic Company of Rio de Janeiro submitted daily vehicle flow data to examine emissions from the downtown district before (2013) and after (2017) the reorganization of urban mobility (CET-Rio). The 1) Passos (400 m), 2) Presidente Antônio Carlos (850 m), 3) Rio Branco (650 m), and 4) 1o March (400 m) avenues were the routes used in this investigation. Between 2013 and 2017, these were the only routes in the city that were monitored. However, because they have a similar traffic flow to neighbouring streets, they are seen as emblematic of the region. The study of Li et al. (2019) was limited in this sense because the authors only looked at four specific road segments with traffic detectors. However, the data could fully represent the impacts of transport.

Inea Resolution No. 67 was utilized to compute highway emissions (INEA, 2013). It outlines a process for developing regional inventories of automobile emissions. As shown in Equation 1, this method uses a bottom-up strategy to predict vehicle emissions.

$$Ei = \sum_i N \times Fi \times d \qquad \text{(eq. 1)}$$

Where,

Ei: Vehicle emission of air pollutant i, in kg day-1;

N: Vehicle flow, in vehicles/day;

d: Distance travelled in the stretches under study, in km;

Fi: Average emission factor of the air pollutant i, in kg km-1.

Municipal ordinances restrict running trucks during periods of heavy traffic flow on the routes chosen, so only urban buses were used to calculate the emissions. Buses were expected to be constructed in 2012 or later, employing technology comparable to that used in the EURO5 standard (CONAMA, 2008). Vehicle emission factors for the Rio de Janeiro bus fleet are shown in Table 2.

Table 2 | Emission factors per pollutant for urban buses of the P7 category and the bus fleet of Rio de Janeiro city for Manufacture year

Manufacture years	*CO (g km-1)*	*NOx (g km-1)*	*PM10 (g km-1)*	*CH4 (g km-1)*	*CO2 (g km-1)*	*Urban buses fleet*
2012	0.54	2.62	0.02	0.06	1.27	859
2013	0.54	2.69	0.02	0.06	1.28	497
2014	0.54	2.69	0.02	0.06	1.28	346
2015	0.48	2.62	0.02	0.06	1.28	437
2016	0.57	2.90	0.02	0.06	1.26	296
P7 (weighted)	0.53	2.68	0.02	0.06	1.27	2,435

Source: Adapted from Cetesb (2016) and Detran-RJ (2018)

2.2 ENERGY CONSUMPTION ESTIMATES

The Municipal Transportation Department supplied information on the operation of city bus services, such as line numbers, monthly distance travelled (km), number of trips paid, and number of passengers transported (SMTR, 2019a). This application programming interface (API) developed by IplanRio company keeps track of the city bus fleet's GPS fitted in vehicles (SMTR, 2019b). In addition, the Federation of Passenger Transport Companies of Rio de Janeiro State provided data on average monthly bus fuel consumption (L km^{-1}) (FETRANSPOR, 2017). Two scenarios [scenario 1 (2013) and scenario 2 (2017)] were created for the evaluation of the energy consumption for a typical month (j = May), that is, a month that does not include school holidays or holidays with a significant influence on traffic, such as Carnival. To compute the energy consumption in each scenario, the monthly distance travelled by the lines that traverse Rio de Janeiro's downtown was first estimated using Equation 2.

$$DMD_{ji} = \sum_{n} DLMD_{ji} \qquad \text{(eq. 2)}$$

Where,

DMD_{ji}: Distance travelled by bus lines in downtown of Rio de Janeiro in month j of year i, in m

$DLMD_{ji}$: Distance travelled by each bus line (n) in downtown of Rio de Janeiro in month j of year i, in meters.

According to Equations 3 and 4, these distances were computed using Google Earth and .kmz files containing all the bus lines (SMTR, 2015).

$$PLD = (DLT/DLD) \times 100 \qquad \text{(eq. 3)}$$

$$DLMD_{ji} = DLM_{ji} \times PLD \qquad \text{(eq. 4)}$$

Where,

PLD: Percentage of the route of each bus line in downtown of Rio de Janeiro, in %

DLT: Total route distance of each bus line in meters

DLD: Distance of the route of each bus line in downtown of Rio de Janeiro, in meters

$DLMD_{ji}$: Distance travelled by each bus line in downtown of Rio de Janeiro in month j of year i, in meters

DLM_{ji}: Distance travelled by each bus line in month j of year i, in meters

Equations 5, 6, and 7 were used to compute the fuel consumption (CFji) and the volumes of mineral diesel (CDMji) and biodiesel (CBji). In May 2013, the percentage of biodiesel in mineral diesel was 5%, while in May 2017, it was 7% (BRAZIL, 2016; CNPE, 2009).

$$CF_{ji} = DMD_{ji} \times FA \quad \text{(eq. 5)}$$

$$CDM_{ji} = (1-p_i) \times CF_{ji} \quad \text{(eq. 6)}$$

$$CB_{ji} = (p_i) \times CF_{ji} \quad \text{(eq. 7)}$$

Where,

CF_{ji}: Diesel Commercial fuel consumption in month j of year i, in Liters

DMD_{ji}: Distance travelled by bus lines in downtown of Rio de Janeiro in month j of year i, in meters

FA: fuel autonomy, in L m^{-1}

CDM_{ji}: Mineral diesel consumption in month j of year i, in Liters

p_i: biodiesel percentage in commercial fuel in month j of year i, in %

CB_{ji}: biodiesel consumption in month j of year i, in Liters

Equations 8, 9, and 10 were used to compute the total usable energy consumption after calculating mineral diesel and biodiesel monthly consumptions in each scenario.

$$CEU_{dMji} = DE_{DM} \times CDM_{ji} \quad \text{(eq. 8)}$$

$$CEU_{Bji} = DE_{B} \times CDM_{ji} \quad \text{(eq. 9)}$$

$$CEU_{Tji} = CEU_{dMji} + CEU_{Bji} \quad \text{(eq. 10)}$$

Where,

CEU_{dMji}: Useful energy consumption of mineral diesel in month j of year i, in MJ/month

DE_{DM}: Energy density of mineral diesel, in tep m^{-3}

CEU_{Bji}: Useful energy consumption of biodiesel in month j of year i, in MJ/month

DE_{B}: Energy density of biodiesel, in tep m^{-3}

CEU_{Tji}: Total useful energy consumption in month j of year i, in MJ/month

2.3 AIR QUALITY MONITORING

The Carioca (-22.908344/-43.178151) automated station collects meteorological parameters, PM_{10}, CO and O_3. In addition, the Castelo (-22.90752/-43.17257) semiautomatic station collects particulate

matter (PM_{10} and $PM_{2.5}$). Both sites are in commercial areas, and vehicles are the primary source of pollution (INEA, 2016b; SMAC, 2013). Both stations were monitored from 2013 to 2017.

Carioca station has a full coverage radius of 2 km and a partial coverage radius of 400 m (SMAC, 2013). Castelo stations have a radius of 500 m (SEA, 2011) (Figure 1).

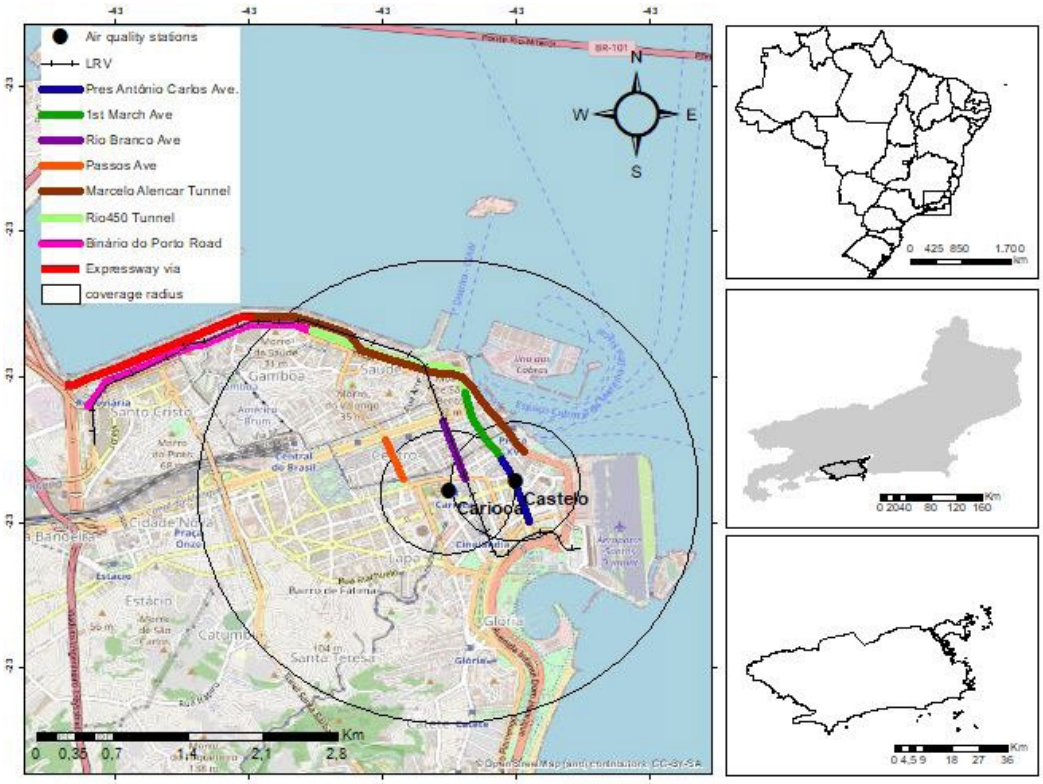

Figure 1 | Aerial view of the coverage radius of the air quality monitoring stations in downtown Rio de Janeiro: 1) Carioca station and 2) Castelo station

Source: Authors

An Ecotech Spirant BAM analyzer using the beta attenuation method was employed to quantify the PM with a diameter < 10 µm (PM_{10}) at the Carioca station. An Ecotech Serinus 30 analyzer with infrared detection was used to evaluate carbon monoxide (CO). Ozone (O_3) was measured using an Ecotech Serinus 10 analyzer that uses the EQOA-0506-160 Reference Method. As this station is automatic, data is provided hourly, except for O_3 data that are provided at each 8 h. Castelo's semi-automatic stations use samplers (Energética, Brazil, models AGVMP10 and AGVMP252) to monitor PM in the coarse (PM_{10}) and fine ($PM_{2.5}$) fractions, for 24 h every six days, encompassing all days of the week, including weekends and wet days (INEA, 2016b). With a volumetric flow rate of 0.019 $m^3\ s^{-1}$, they sample PM on glass fibre filters (Millipore, USA) positioned approximately 1.5 m above the ground level. Gravimetric analysis was used to determine the PM's mass. The filter was weighed before and after collection on an analytical balance (Mettler E., Zürich, Switzerland, ±0.0001 g) (NBR 13412).

Multivariate analysis techniques were used to verify the atmospheric behaviour in the downtown area, namely a hierarchical clusters analysis (HCA), which uses the Ward method with scaled distances, and a correlation matrix, which uses hourly data for meteorological variables like precipitation (Prec), pressure (P), relative humidity (RH), temperature (T), solar radiation (SR), wind direction (WD), and wind speed (WS), together with air pollutant data for PM_{10}, SO_2, O_3, and CO monitored at the Carioca station in 2013 and 2017. All statistical analyses were performed using the Statistical Computing Platform "R" (R Development Core Team, 2017).

3 RESULTS

3.1 VEHICULAR EMISSIONS

Pollutant levels of CO, NO_x, PM_{10} (kg), and GHG (CH_4 and CO_2) emitted by circulating buses in downtown Rio de Janeiro, before (2013) and after (2017) the urban mobility reorganization were measured using the methods employed in the vehicle emissions inventory (Table 3).

Table 3 | Pollutant emissions (kg) in the main avenues in downtown Rio de Janeiro before (2013) and after (2017) mobility changes

Avenue/pollutant (kg)	*2013*					*2017*				
	CO	*NO_x*	*PM_{10}*	*CH_4*	*CO_2*	*CO*	*NO_x*	*PM_{10}*	*CH_4*	*CO_2*
Passos	262	1,316	10	29	626	294	1,479	11	33	704
Antônio Carlos	1,789	8,993	67	201	4,278	936	4,706	35	105	2,239
Rio Branco	1,135	5,704	43	128	2,714	1,160	5,829	44	131	2,773
1º de Março	90	454	3.4	10	216	67	335	2.5	7.5	159
Total	3,276	16,467	120	368	7,834	1,413	12,349	90	276	5,875
Contribution (%)	12	59	0.4	1.3	28	7.1	62	0.4	1.4	29

Source: Authors

Bus emissions were dominated by nitrogen oxides (NO_x), which accounted for 59-62% of the total emissions, followed by carbon dioxide (CO_2), a greenhouse gas, which accounted for 28-29%. PM_{10}, CH_4, and CO accounted for 0.4%, 1.3-1.4%, and 7.1-12% of the total emissions, respectively. CO is a pollutant associated with light-duty cars, whereas NOx is the primary indicator of heavy-duty vehicles.

3.2 ENERGY CONSUMPTION

In May 2013, the total distance travelled by buses in scenario 1 was 2,417,970 km, while in scenario 2, it was 2,224,896 km (Table 4). The restructuring of traffic resulted approximated in an 8% reduction such in the distance travelled by buses downtown as in a reduced fuel consumption in 2017 compared to 2013. The estimated vehicle fuel consumption was 0.39 L km^{-1}, with no variation between 2013 and 2017.

Table 4 | Useful energy consumption, in MJ, in scenario 1 (May 2013) and scenario 2 (May 2017)

Fuel	*May 2013*		*May 2017*	
	Mineral Diesel	*Biodiesel*	*Mineral Diesel*	*Biodiesel*
Consumption (L)	895,858	47,150	798,293	69,417
Energy densities (MJ L^{-1})	35.5058	33.1610	35.5058	33.1610
Useful energy consumption (MJ)	31,808,109	1,563,557	28,343,985	2,301,931
Total useful energy consumption (MJ)	33,371,666		30,645,916	
Total distance travelled (km)	2,417,970		2,224,896	
Total commercial diesel (L)	943,008		867,710	

Note: Energy densities: 0.848 toe-m^{-3} for mineral diesel and 0.792 toe-m^{-3} for biodiesel (MMA, 2013).

Source: Authors

3.3 AIR QUALITY ASSESSMENT

Data from the monitoring sites were compared to the Brazilian Ambient Air Quality Standards (BAAQS) established by Conama Resolution No. 491/2018 (CONAMA, 2018), which came 28 years after the initial resolution (Conama 03/90). For Carioca and Castelo stations, Tables 5 and 6 show the maximum yearly concentrations from 2013 to 2017, indicating short-term exposure and annual mean concentrations representing long-term exposure.

PM_{10} concentrations in the downtown zone were the lowest over the research period at both sites in 2017, with a decrease in both long- and short-term exposures. PM_{10} mean concentrations fell from 12% and 25% between 2013 and 2017, respectively. High PM_{10} concentrations were reported in 2015, linked to increased infrastructure construction in the downtown area. In addition, in 2015 (48 µg m^{-3}) and 2016 (42 µg m^{-3}) of PM_{10}, long-term exposure values beyond the BAAQS limits were detected. In 2016, a decrease in PM_{10} concentrations was observed in response to the urban mobility reorganization.

Table 5 | Long-term (annual mean concentrations) and short-term (maximum annual concentrations) analysis for all pollutants monitored at the Carioca station from 2013 to 2017

Pollutant	*Year*	*N*	*Long-term exposure*				*Short-term exposure*			
			C_{mean}	*BAAQS*	ΔC_{mean}¹ *(%)*	ΔC_{mean}² *(%)*	$C_{máx.}$	*BAAQS*	ΔC_{max}¹ *(%)*	ΔC_{max}² *(%)*
PM_{10} 24h (µg m^{-3})	2013	353	33	40	-	-	104	120	-	-
	2014	324	35	40	6.2	6.2	88	120	-16.0	-16.0
	2015	360	35	40	6.2	-0.5	106	120	1.1	20.4
	2016	354	30	40	-8.3	-13.3	102	120	-2.2	-3.3
	2017	345	29	40	-13.6	-5.8	78	120	-23.5	-21.7
CO 8 h (daily maximum rolling average) (ppm)	2013	354	-	-	-	-	2.2	9	-	-
	2014	339	-	-	-	-	1.8	9	-18	-18
	2015	363	-	-	-	-	1.6	9	-24	-8
	2016	348	-	-	-	-	1.9	9	-10	19
	2017	355	-	-	-	-	1.8	9	-18	-9
O_3 8 h (daily maximum rolling average) (µg m^{-3})	2013	356	-	-	-	-	89	140	-	-
	2014	345	-	-	-	-	85	140	-4	-4
	2015	363	-	-	-	-	107	140	21	26
	2016	354	-	-	-	-	112	140	27	5
	2017	345	-	-	-	-	111	140	26	-1

Note:

Cmean – annual mean concentration

Cmax – annual maximum concentration

ΔCmean – mean concentration of one year in relation to some year

ΔCmax – maximum concentration of one year in relation to some year

1 – in relation to the concentration obtained in 2013

2 – in relation to the concentration obtained in previous year

Source: Adapted from Seconserma (2018) and Inea (2018).

Table 6 | Long-term (annual mean concentrations) and short-term (maximum annual concentrations) analysis for all pollutants monitored at the Castelo station from 2013 to 2017

Pollutant	Year	N	Long-term exposure				Short-term exposure			
			C_{mean}	BAAQS	ΔC_{mean}¹ (%)	ΔC_{mean}² (%)	$C_{máx.}$	BAAQS	ΔC_{max}¹ (%)	ΔC_{max}² (%)
	2013	55	40	40	-	-	108	120	-	-
PM_{10}	2014	52	40	40	-1.4	-1.4	95	120	-12.0	-12.0
24 h	2015	44	48	40	19.3	21.0	119	120	10.2	25.3
($\mu g\ m^{-3}$)	2016	36	42	40	1.8	-14.6	69	120	-36.1	-42.0
	2017	42	34	40	-17.2	-18.7	85	120	-21.3	-23.2
	2013	58	18	20	-	-	58	60	-	-
$PM_{2.5}$	2014	52	16	20	-10.3	-10.3	36	60	-37.9	-37.9
24 h	2015	40	17	20	-10.0	0.3	30	60	-48.3	-16.7
($\mu g\ m^{-3}$)	2016	48	16	20	-16.4	-7.1	40	60	-31.0	33.3
	2017	36	12	20	-37.6	-25.4	32	60	-44.8	-20.0

Note:

Cmean – annual mean concentration

Cmax – annual maximum concentration

ΔCmean – mean concentration of one year in relation to some year

ΔCmax – maximum concentration of one year in relation to some year

1 – in relation to the concentration obtained in 2013

2 – in relation to the concentration obtained in previous year

Source: Adapted from Seconserma (2018) and Inea (2018).

$PM_{2.5}$ concentrations in 2017 were compared to previous years. Furthermore, none of the recorded values was higher than the BAAQS for short-term exposure at the Carioca station during any monitored years. According to Table 6, there was a 38% reduction in yearly $PM_{2.5}$ mean concentrations before (2013) and after (2017) the reorganization of urban transportation.

The highest CO values were recorded between 18:30 and 20:30. This interval reflects peak transit times when people leave work, and traffic bottlenecks occur daily. CO is a contaminant emitted by automobiles circulating in the area due to the incomplete combustion of fossil fuels. The mean concentration (8 h) was five times lower than the BAAQS (9 ppm). Ozone was the only pollutant that showed 8-hour average concentrations greater in 2015, 2016, and 2017 compared to 2013. Furthermore, a declining trend was not seen during the monitored period, and the levels of O_3 were above the BAAQS. To further understand this trend, researchers are tracking VOCs and NO_x, precursors of O_3 in the atmosphere, via photochemical reactions (ARBILLA *et al.*, 2002; ATIKINSON, 2000). However, both pollutants were not monitored in the Carioca station.

Hierarchical cluster analysis (HCA) was performed on all meteorological variables and pollutants monitored at the Carioca station from 2013 to 2017 to examine the atmospheric behaviour in downtown Rio de Janeiro. The analysis demonstrated a high degree of similarity between air pollutants (PM_{10}, O_3, SO_2, and CO) and meteorological variables that dictate how local atmospheric dispersion occurs (Figure 2). PM_{10}, RH, WD, and solar radiation (SR) were grouped together. Some researchers have already looked into the impacts of the PM-SR correlation because black carbon is present in PM, absorbing solar radiation (GODOY *et al.*, 2009; VENTURA *et al.*, 2017, 2019b). However, no correlation was found between pressure and any of the variables evaluated.

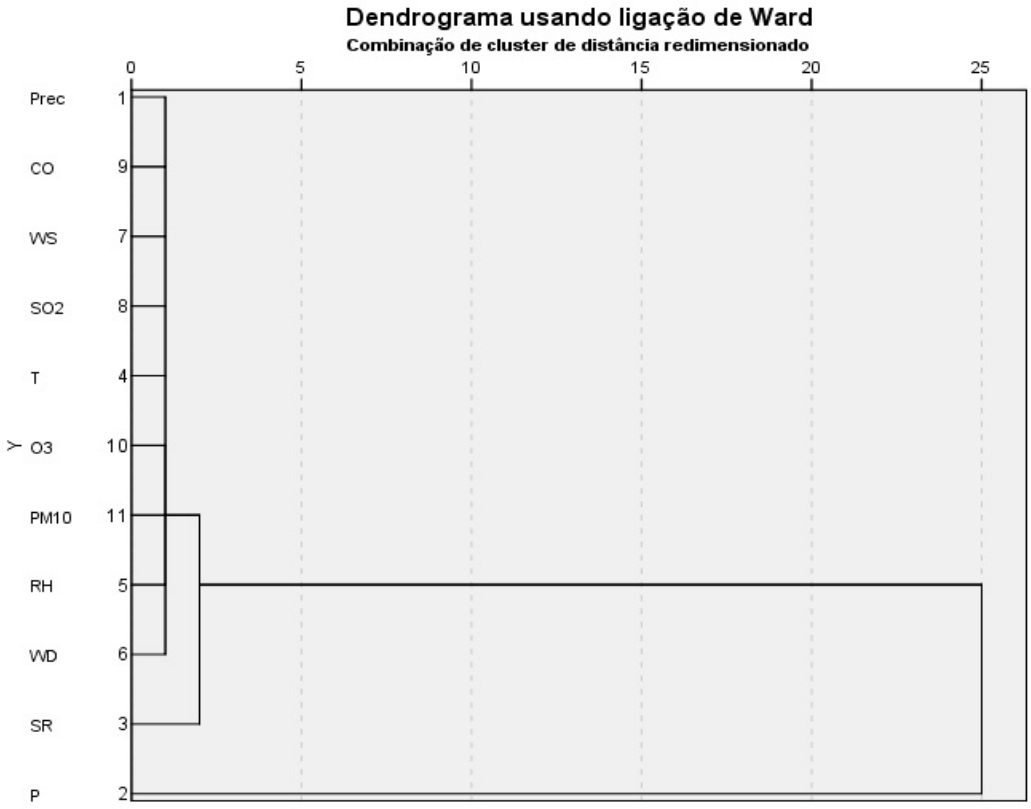

Figure 2 | Dendrogram of meteorological variables and pollutants monitored at the Carioca station from 2013 to 2017

Source: Authors

Precipitation did not show correlations with any other variable. The precipitation is the result of all meteorological variables working together. O_3 had a positive connection with T, SR, and RH, as expected. This pollutant is produced by photochemical processes and in the presence of SR, which has a strong relationship with temperature (0.70). Furthermore, both T and SR were associated with RH (-0.55 and -0.77), as seen in prior research focusing on Rio de Janeiro (VENTURA *et al*., 2017, 2019b). Ozone also had a weak relationship with wind variables (-0.31 and 0.46) owing to its low density, which allows it to be transported to and from different places depending on WD and WS. The multivariate study highlights that higher O_3 levels are more likely to occur on days with low RH and sunny days with high temperatures.

PM_{10} from vehicular emissions showed a moderate connection with CO (r = 0.53). It should be noted that these contaminants are not affected by weather conditions. As a result, the decrease in these atmospheric pollutants is more likely related to traffic than meteorological fluctuations.

4 DISCUSSION

Reduced urban bus lines, restrictions on light vehicles, changes in road infrastructure, and the implementation of LRVs, cable cars, and bike paths were all part of the urban mobility plan designed for the downtown region of Rio de Janeiro to host the 2014 Fifa World Cup FIFA and the 2016 Olympic Games. The works took place from September 2011 to June 2016. Based on this traffic restructuring, buses covered shorter routes, used less fuel, and produced fewer emissions, improving air quality. Compared to 2013, the pollutants generated by buses on the main roadways in the downtown area decreased by 25% in 2017. Antônio Carlos Avenue showed the most significant drop (48%), followed

by 1° de Março Ave (26%). This was due to the improvement of bus routes and the opening of a new tunnel and the Via expressway. However, in Passos Ave. there was a 12 % increase in emissions because most of the buses started to circulate after Rio LTVs operation (2017). There was no significant change in the characteristics of the vehicular flow in Rio Branco Ave. because only changes in light-duty vehicles transit occurred, whereas buses kept circulating at nearly the same rate. This means 7,000 kg of pollutants, such as GHGs, are no longer discharged into the atmosphere each month. The energy consumption estimation revealed that the reorganization in urban mobility, driven by the reduction of circulating bus lines in the region, resulted in an 8% reduction in the distance travelled by buses in this area. Biodiesel consumption by buses increased by 47% from 2013 to 2017, while mineral diesel consumption decreased. This is primarily due to the Brazilian government's increasing biodiesel percentage in commercial fuel from 5% in 2013 to 8% in 2017.

The air quality in downtown Rio de Janeiro improved in response to urban transportation optimization activities, infrastructure improvements performed in 2016, and modifications in the fuel mix. The annual mean concentrations of particulate matter (PM_{10} and $PM_{2.5}$) decreased by 38% between 2013 and 2017, while CO maximum concentrations decreased by 18%. These findings matched those seen in other places, such as Toronto, Canada. After reorganizing their urban transportation, Paris, France, and Beijing, China, will host major sporting events such as the World Cup and the Olympic Games (BIGAZZI; ROULEAU, 2017; CHAKHTOURA; POJANI, 2016; GUO *et al.*, 2013; LI *et al.*, 2011).

Ozone concentrations, however, increased but did not surpass the national limits. Because intricate photochemical reactions create this pollutant, it is not easy to manage. Rio de Janeiro has a history of high ozone levels. Increased O_3 concentrations were evaluated in research conducted during the partial shutdown due to COVID-19 when there was a significant drop in car traffic (DANTAS *et al.*, 2020). The authors found that as NO_x levels fell, O_3 levels rose. The increase in O_3 levels was ascribed in another study to high ratios of NO_x/NO in various Rio de Janeiro islands (GIODA *et al.*, 2018). Ozone levels were also much higher during and after the Olympic season when traffic was reduced and managed (DE LA CRUZ *et al.*, 2019). NO_x levels, on the other hand, were lower, indicating a direct involvement in O_3 production. NO_x and O_3 were not observed at the sites we investigated, but the calculated NO_x emissions suggested a 25% reduction. This could be a sign of increased O_3 formation.

5 CONCLUSIONS

Vehicle emissions are the primary source of pollutants in many large cities. This study found that a well-executed plan to improve urban mobility, such as in Rio de Janeiro's downtown region, with reductions in urban bus lines, restrictions on light vehicles, changes in road infrastructure, and the implementation of LRVs, resulted in environmental benefits, particularly for the local environment. Between 2013 and 2017, a reduction of 8% in energy consumption by buses resulted in a reduction of up to 25% in GHG emissions. In addition, the air quality in the downtown zone improved by 14 –45% in terms of major pollutants (PM_{10}, $PM_{2.5}$, and CO). On the other hand, secondary pollutants (O_3) increased in response to weather conditions and reduced VOC_s and NO_x levels. It is concluded that proper traffic management methods and urban mobility enhancements can assist in limiting the consequences of emissions, air pollution concentrations, human exposure, and environmental impacts.

The lack of monitoring data is one of the limitations of this work. Nonetheless, the results were valuable because they demonstrated that clever measures could produce excellent results. Traffic management, which includes real-time volume, speed, and categorization monitoring, allows for in-depth and extensive research. From our perspective, the best way to construct an urban mobility plan is for key stakeholders (*i.e.*, Municipal Authorities, Public Administration, Environmental Agencies, Transport Authorities, etc.) to collaborate on policies and strategies to achieve beneficial outcomes for the region.

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The lack of cumulative impact analysis in the environmental licensing of the Industrial Port Complex at Pontal do Paraná, on the southern coast of Brazil

A ausência de análise de impactos cumulativos no licenciamento ambiental do Complexo Industrial Portuário, Pontal do Paraná, litoral sul do Brasil

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ARTICLE- VARIA

ABSTRACT

The Environmental Impact Assessment is an environmental policy instrument developed in response to societal concerns about the negative impacts of major development projects and the recognition of planetary boundaries. In Brazil, it is part of the environmental licensing process, which also encompasses various weak points. Cumulative Impacts (CIs) from multiple interventions (both natural or anthropic) across specific spaces and time frames are routinely dealt with poorly. The installation of an Industrial Port Complex (IPC) at Pontal do Paraná, a municipality on the south coast of Brazil is currently undergoing an environmental licensing process. This article analyzes five projects' Terms of Reference (TR) and Environmental Impact Studies (EIS) to verify if and how the IPC projects assess CIs. The results suggest that TRs and EISs provide insufficient to assess CIs. In the political-procedural sphere, there is no institutionalization for Cumulative Impact Analysis. Moreover, even if it is performed, it is essential to consider how power relations affect the public acceptance of mega-projects. Locally, uncertainty about CIs reflects into scenarios of environmental unsustainability.

Keywords: Cumulative Impact Assessment. Environmental Impact Study. Territorial Planning. Atlantic Forest.

RESUMO

A Avaliação de Impacto Ambiental é um instrumento da política ambiental que surge como resposta às preocupações da sociedade sobre os impactos negativos dos empreendimentos e ao reconhecimento dos limites planetários. No Brasil, está inserido no processo administrativo do Licenciamento Ambiental, no qual fragilidades coexistem. Os Impactos Cumulativos (ICs), resultantes de múltiplas alterações decorrentes de intervenções (naturais ou antrópicas) concentradas espacial e temporalmente, corriqueiramente, recebem tratamento insuficiente. A instalação de um Complexo Industrial Portuário (CIP) no município de Pontal do Paraná está em fase de licenciamento ambiental. Este artigo objetivou verificar se e como os projetos do CIP avaliam os ICs por meio de análise documental dos Termos de Referência (TR) e Estudos de Impacto Ambiental (EIA) de cinco empreendimentos. Os resultados apontam que os TRs e EIAs são insuficientes na análise dos ICs. No âmbito político-procedimental, não há institucionalização para a prática de Análise de Impactos Cumulativos. Mesmo que ela ocorra, é imprescindível considerar o peso das relações de poder para aceitação pública de megaempreendimentos. Localmente, as incertezas sobre os ICs refletem cenários de insustentabilidade ambiental.

Palavras-chave: Avaliação de Impactos Cumulativos. Estudo de Impacto Ambiental. Planejamento Territorial. Floresta Atlântica.

1 INTRODUCTION

Research and practice on cumulative impacts are at their early stages in Brazil. However, it is essential to guide initiatives that prevent and address socio-environmental problems (DIBO, 2018). This field of knowledge is aligned with the policy of preventive environmental management and is part of the more extensive Environmental Impact Assessment (EIA) framework (MORGAN, 2012). The EIA emerged as a response from governments and scientists to the impacts of industrialization on human and environmental health. This technical-institutional approach is aligned with moderate environmentalism, i.e., ecological modernization, which argues it has the potential to overcome conflicts between economic development goals and environmental endeavours (MILANEZ, 2009; PI PUIG, 2019).

In Brazil, the technical instrument of EIA is part of the Environmental Licensing process[1], one of the mechanisms used to approve project implementation as part of the National Environmental Policy (BRASIL, 1981). Therefore, the EIA process encompasses the steps needed to assess if a specific proposal might affect the current environmental conditions and informs the decision-making process of environmental licensing. Any activities that modify the environment are subject to approval from the environmental agency responsible for granting a three-phase environmental license (Preliminary License – PL, Installation License – IL, and Operating License – OL) (SÁNCHEZ, 2020).

This article focuses on Major Development Projects (MDPs), which are primarily linked to transforming environmental spaces into infrastructures to extract territorial goods (e.g., ore, agricultural resources, electricity, and oil) and provide logistical support for their transportation (roads, ports, railways, gas pipelines, polyducts, etc.). Since the 1970s, these projects have been led by the private sector (large corporations) and enabled by the State via sectoral macro-policies, planning, and ordinances so these projects can be financed through plans, programs, and multilateral banks (BERNO DE ALMEIDA *et al.,* 2010; CASTRO, 2012; GUSMÃO, 2010; VAINER, 2007).

Due to their socio-environmental consequences, the political and procedural aspects for approving MDPs have drawn the attention of Political Ecology researchers. According to Acselrad (2011) and Zhouri (2008), MDPs are part of a violent process that expropriates family farmers, artisans, peasants, and indigenous peoples whose sustenance and production are natural, common goods. Furthermore,

the project impacts are not democratic, i.e., risks and uncertainties are unevenly distributed and affect populations that are already historically vulnerable. According to Acselrad (2011), "the project planners or investors tend to minimize the presence of certain populations in the areas where they intend to settle," from the conception of territorial planning to the "active lack of knowledge" of how the projects being licensed will affect these groups (PHASE *et al.*, 2011, p. 26).

Nevertheless, Acselrad (2011) considers that no development project should be carried out under the pretext of progress, sacrificing social groups and causing incalculable environmental costs. On the other hand, as the main instrument for approving Major Projects, the EIA reproduces conventional methods, including the separation of biophysical aspects and socio-political and cultural dimensions, as well as the difficult discussion about the relationship between environmental equity and social and environmental inequality (LEROY; ACSELRAD, 2011). Fase, Ettern, and Ippur (2011) and Zhouri (2008) point out that the EIS/EIRs (or, in Brazilian Portuguese, *Estudo de Impacto Ambiental*, EIA, and *Relatório de Impacto Ambiental*, RIMA) have been converted into a reactive assessment of public approval for projects in the social and political sphere, rather than a proactive, assertive mobilization around the environmental impacts to inform the decision-making process. That adds to the numerous battles and legal disputes arising from non-compliance, technical differences, licensing competence, and the lack of and/or insufficient engagement from the people. The Public Ministry (PM) of the Union and States have performed numerous interventions targeting the lack of transparency and misconduct that often cause the judicialization processes, which are a mark of Brazilian environmental licensing (HOFMANN, 2015, p. 41; 57-59).

In the EIA process, Cumulative Impacts (CIs) are often disregarded, despite calls from the scientific community, social groups, and movements warning about their importance. CIs result from anthropic or natural actions concentrated in specific spaces and time frames, and that cause a substantial change in socio-environmental systems (OLAGUNJU; GUNN, 2015). In this sense, Sánchez (2020, p. 280) defines that "cumulative impacts are the entire effects on an environmental resource, ecosystem or community, regardless of the origin of its causes."

That is the backdrop for a discussion surrounding the significance of small enterprises and their impacts: although they can be considered insignificant individually, they might cause irreparable damage from a cumulative perspective. Similarly, projects analyzed individually may have significantly lower impacts than perspectives that take into account if they are concentrated in a specific spatial or time frame (CLAYS; PEREIRA, 2019; DUARTE *et al*., 2017; MONTAÑO *et al.*, 2014; SANCHEZ, 2020). Following this view, Siqueira-Gay *et al.* (2019) add to the discussion around potentially significant impacts resulting from the installation of a set of small hydroelectric plants (SHPs), especially in the Amazon region, and their neglected cumulative impacts: "when the small is not beautiful."

In Brazil, institutionally, there is no specific regulation regarding Cumulative Impact Assessments (CIAs). However, regarding the impact and alternative analysis, the Brazilian National Environment Council (Conama) Resolution No. 1/1986 suggests/recommends considering the description of "their cumulative and synergistic properties; the distribution of social burdens and benefits" (CONAMA, 1986). Despite this recommendation to analyze CIs in the context of the EIA, other instruments like the Strategic Environmental Assessment (SEA) and the Integrated Environmental Assessment (IEA) have been employed when planning hydrographic basins, especially for the same type of enterprise, i.e., hydroelectric plants and SHPs in the Amazon (GALLARDO *et al.,* 2017; SIQUEIRA-GAY *et al.,* 2019).

In Brazil, tensions and disputes have followed the environmental licensing of large projects amidst systematic dismantling and environmental deregulation (BARCELOS, 2020; ZHOURI, 2008). At regional and local levels, the MDP-based development model has been advancing rapidly (ALÍER, 2007). In Paraná, a state in southern Brazil, the economy has been following a model based on competitiveness and agribusiness integration networks. Thus, these regions are centred around their primary products

(soybean, coffee, and electricity) and their port-based logistic framework (SILVA; GONÇALVES, 2019). Regarding the latter, the coastal region of Paraná has a hub that encompasses the Port of Paranaguá and Antonina, located in the Paranaguá Estuarine Complex. Industrial port activity expanded in recent decades, causing changes in the occupation and use of these territories for capital accumulation (ABRAHÃO; CANEPARO, 2014; CUNHA, 2018).

The present case highlights the municipality of Pontal do Paraná and the intent to convert a territory that is currently used mainly by the beach tourism sector and is strongly marked by the presence of traditional fishing communities (PIERRI *et al.,* 2006) into an industrial port complex (CUNHA, 2018). Therefore, considering the set of five MDPs undergoing the licensing process that constitutes the Industrial Port Complex (IPC) of Pontal do Paraná, this article aims to analyze if and how the Terms of Reference and the Environmental Impact Studies of these projects address cumulative impacts. Therefore, the next section of this article focuses on the context of Pontal do Paraná, the projects, and the disputed territories, followed by the methodology, the results, the discussion, and the final considerations.

2 PONTAL DO PARANÁ: MAJOR DEVELOPMENT PROJECTS AND DISPUTED TERRITORIES

The coast of Paraná plays a vital role in nature conservation due to its social biodiversity potential and being home to the most extensive continuous remnants of the Atlantic Forest (PDS LITORAL, 2019). On the other hand, it faces severe social vulnerability problems (AZEVEDO, 2016), abandonment policies (TIEPOLO, 2016), and conflicts surrounding plans for the territory (CALDEIRA, 2018; CUNHA, 2018). That resulted in significant disputes over the social and spatial production therein, accompanied by capital accumulation to the detriment of Pontal do Paraná's sociocultural and natural vocations (AZEVEDO, 2016; CALDEIRA, 2018; CUNHA, 2018; TIEPOLO, 2016).

The urbanization process of Pontal do Paraná was directly connected to the private sector and involved a public land concession contract for a company, "Balneária Pontal do Sul," in 1950. That shows the history of the privatization of public lands that triggered territorial conflicts with fishing communities and the contradictions surrounding the municipality's territorial planning (CUNHA, 2018).

Pontal do Paraná is mainly a beach municipality geared towards tourists (IPARDES, 2022). However, since the 1980s, there have been port and oil ventures (Tenenge; CBC Heavy Industries S.A., a representative of Mitsubishi Motors in Brazil; Techint; and FEM – Projects, Constructions, and Assembly), but in the following years, these initiatives declined and were deactivated (CUNHA, 2018). Among the municipalities on the south coast, Pontal do Paraná has the highest population growth, mainly due to new industrial and port initiatives. Estimates indicate that, in 2035, the municipality might double the population (amounting to approx. 50 thousand inhabitants) when compared to these figures for 2010 (when it had 20,920 inhabitants) (PDS LITORAL, 2019). Regarding social vulnerability, according to Azevedo (2016), there is a rural sector with 177 residents who are considered highly vulnerable. For the author: "about 38% live in areas of medium social vulnerability, and just over 0.5% live in a high vulnerability sector, the Maciel fishing community" (AZEVEDO, 2016, p. 114). Data from 2008 show that fishing is the main occupation of 2% of the population of Pontal do Paraná, totalling approx. 400 people, according to Colônia de Pescadores, a fisherman organization with 13 locations spread around the municipality (CALDEIRA; PIERRI, 2014). It is also important to point out the presence of the original Guarani peoples in the Sambaqui Indigenous Land, a protected area yet to be titled (INSTITUTO SOCIOAMBIENTAL, 2020).

The Industrial Port Complex proposed for Pontal do Paraná includes installing five new projects[2] requiring an EIS/EIR for environmental licensing. These projects are: A. 3P Porto Pontal, also known as Pontal do Paraná Container Terminal (PPCT); B. Melport Maritime Terminals; C. Odebrecht; D. Subsea7;

and E. New Infrastructure Lane. All are located near the Guaraguaçu River, and four are in front of the Indigenous Land of Ilha da Cotinga. Project D overlaps with the Sambaqui Indigenous Land and 15 other areas occupied by traditional communities, composed mainly of fishermen, who will be directly or indirectly affected (Figure 1).

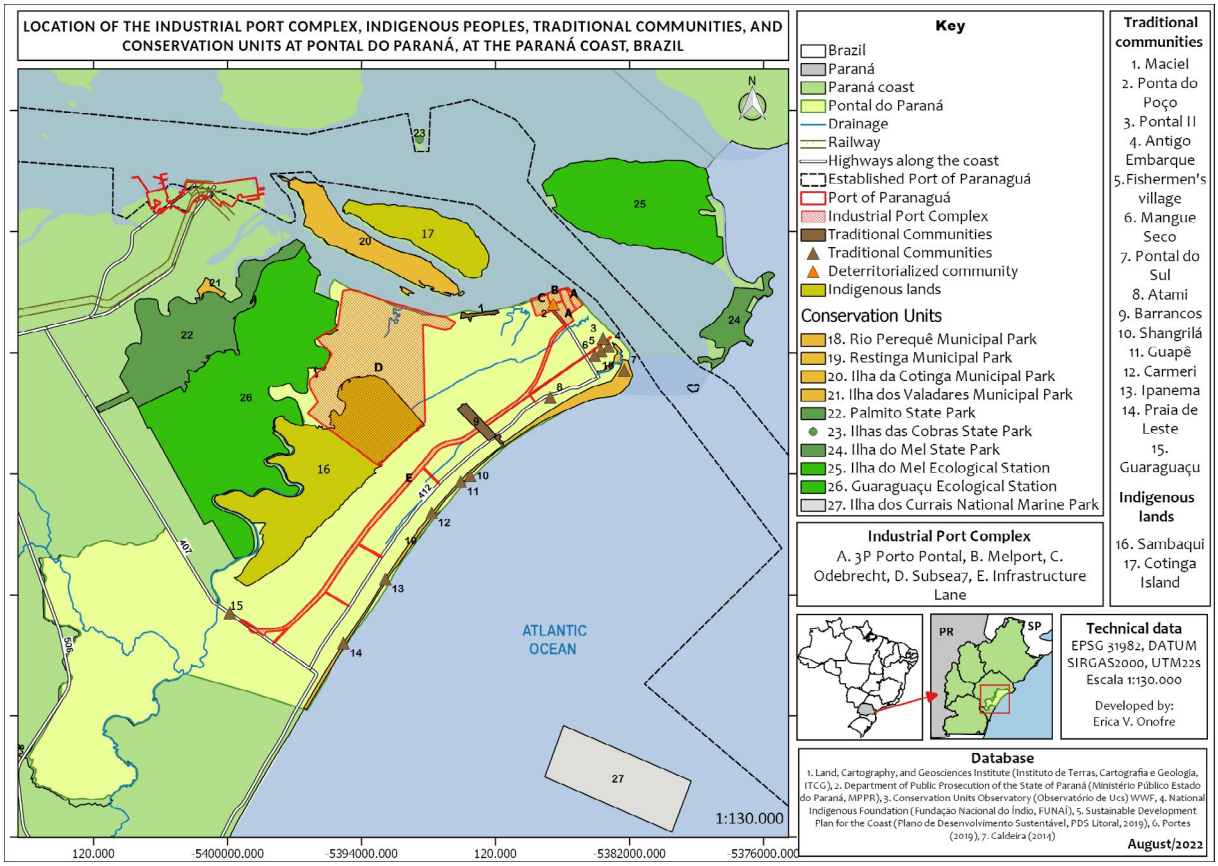

Figure 1 | Location of the Industrial Port Complex, Traditional Peoples, Communities, and Conservation Units at Pontal do Paraná, at the Coast of Paraná

Source: Authors (2021).

3 METHODOLOGY

The documentary analysis method adopted consists of three steps: (1) thematic contextualization; (2) origin, historical context of when the document was produced, authorship, goals, and target audience identification; and (3) scheme and analysis of the document (LÉTOURNEAU, 2011). Steps 1, 2, and part of 3 (the scheme) are when most of the document consultation process takes place. In this sense, for the present article, the thematic contextualization encompassed establishing a definition of environmental licensing, EIA, and its procedures. Therefore, step 2 is included in Table 1 below. The document scheme is based on the items analyzed and how these analyses were performed, as shown in Table 1. Four Terms of Reference[3] (TRs) and the five environmental impact studies of the five MDPs undergoing the licensing process in Pontal do Paraná (Table 1) were analyzed (Table 1). They were obtained with the help of the Coastal Observatory (OC2) of the Coast of Paraná (OC2) and researchers linked to the Geography Postgraduate Program of the Federal University of Paraná. The documents were accessed in the second half of 2019 and consulted between 2019 and 2021.

Table 1 | *Description of the projects undergoing the licensing process in Pontal do Paraná, Paraná coast (Brazil), and documents analyzed*

Document	*Enterprise*	*Licensing Agency / Phase*[4]	*EIS Year*	*Project*
TR and EIS – 3P Porto Pontal (3P)	Porto Pontal Paraná Importação e Exportação Ltda.	Ibama / IL subject to the construction of a new highway.	2007 and 2010[5]	Private
Description: The project encompasses "mooring structures, open-air storage areas, and internal pathways, warehouses, as well as administrative and support structures" (AMB PLANEJAMENTO AMBIENTAL, 2007). The project is estimated at BRL $1,500,000,000.00.				
TR and EIS – Melport Terminais Marítimos Ltda. (MTM)	Melport Terminais Marítimos Ltda	IAP / PL has been issued	2014	Private
Description: Multifunctional terminal for liquid storage, a general cargo warehouse, a container yard, and offshore logistical support (ENVEX et al., 2014). The project is estimated at BRL 100,000,000.00.				
TR and EIS - Infrastructure Lane	DER (Department of Roads of the State of Paraná)	IAP / IL (under legal dispute by the Department of Public Prosecution of Paraná - MP-PR)	2016	Public
Description: The work consists of implementing a new highway (Via Arterial) connected to the state highway PR-412 (four collector lanes); expansion and correction of an existing channel by the DNOS (Departamento Nacional de Obras de Saneamento, National Department of Sanitation Works); railroad implementation; pipeline deployment; transmission and sanitation pipelines implementation (ENGEMIN, 2016). The project is estimated at BRL 270,000,000.00.				
EIS[6] - Wharf and dredging refurbishment – Odebrecht (ODB)	Construtora Norberto Odebrecht S.A.	IAP / Licensing withdrawn after Operation Car Wash	2011	Private
Description: The project consists of the readjustment of the quay for the mooring of ships and dredging to deepen the Galheta Channel. It is estimated at BRL $15,000,000.00 (MRS ESTUDOS AMBIENTAIS, 2011).				
TR and EIS – Base de soldagem Subsea7 do Brasil (SS7)	Subsea7 do Brasil Serviços Ltda	IAP/LP granted and canceled	2009	Private
Description: Norwegian construction and engineering company focused on oil and gas exploration subsea bases. The project is estimated at BRL 103,000,000.00 (AAT, 2009).				

Note: Ibama (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis, Brazilian Institute of the Environment and Renewable Natural Resources) is the national environmental licensing agency. In contrast, the IAP (Instituto Ambiental do Paraná, Paraná Environmental Institute), currently called IAT (Instituto Água e Terra, Water, and Land Institute), is the state Environmental licensing agency. Other acronyms: IL = Installation License; PL = Preliminary License; TR = Terms of Reference; EIS = Environmental Impact Study.

Source: The authors, based on the EISs, Cunha (2018), and Ibama (2020) and Pigosso (2018).

To verify whether the TRs and EISs deal with cumulative impacts or not, we searched for the Brazilian Portuguese equivalents of "cumulative," "cumulativeness," "synergy," and "synergistic" in the environmental prognosis chapter. This section was chosen because it appears after the environmental diagnosis, which provides the basis for forecasting and analyzing the impacts and proposing any mitigating and/or compensatory measures. As Sánchez (2020) explains, the environmental diagnosis is a step before the environmental prognosis. The diagnosis enables one to "obtain and organize the information needed to identify and forecast the impacts," i.e., it provides the benchmark to assess the impacts, which is done in the next step, the environmental prognosis (SÁNCHEZ, 2020, p. 182). Since this analysis focuses on the impact assessment, this section is considered the most relevant one. The content indicated by the keywords was then read to analyze how the cumulative impacts were addressed. That was done following the content analysis criteria of Cooper and Sheate (2002), adapted

by Barros and Pereira (2019), as described in Table 2. It was analyzed whether the document meets ("Yes"), does not meet ("No"), or partially meets ("Partially") each criterion.

Table 2 | Criteria used to analyze the Terms of Reference (TRs) and Environmental Impact Studies (EISs) of Major Development Projects undergoing the licensing process in Pontal do Paraná, on the Paraná coast, Brazil

A. Do the TR demand for the cumulative impacts (CIs) to be considered**?
B. Do the EISs mention the terms "cumulative", "cumulativeness", "synergy"*, "synergistic"*?
C. Do the EISs define "cumulative environmental impacts," "cumulativeness," or "synergy"*?
D. Do the EISs identify CIs for the planning*, implantation, operation, and deactivation* phases?
E. Are the CIs described in qualitative terms? If yes, how?*
F. Are the CIs described in quantitative terms (magnitude prediction)?
G. Is the methodology used to identify and assess CIs described and applied?
H. Are the CI study limitations identified and described?

*Source: Created and adapted by the author based on Cooper and Sheate (2002), as adapted by Barros and Pereira (2019). Key: **criterion included by the authors; *Added by the authors*

4 RESULTS AND DISCUSSION

Based on the document analysis criteria, these were the results for the four Terms of Reference (TRs) and the five Environmental Impact Studies (EISs) (Table 3).

Table 3 | Compliance of the Terms of Reference (TRs) and Environmental Impact Studies (EISs) in relation to the criteria analyzed for the Major Development Projects (MDPs) under licensing in Pontal do Paraná, at the Paraná coast, Brazil

Criterion	*Criteria assessment*	*Projects*
A. Do the TR demand for the Cumulative Impacts (CIs) to be considered?	Yes	Melport and Infrastructure Lane
	No	PPCT; Subsea7
	Partially	-
B. Do the EISs mention the terms "cumulative"; "cumulativeness"; "synergy"*; "synergistic"?	Yes	PPCT; Subsea7; Melport; Infrastructure Lane
	No	Odebrecht
	Partially	-
C. Do the EISs define "cumulative environmental impacts", "cumulativeness", or "synergy"?	Yes	-
	No	PPCT; Odebrecht; Melport; Infrastructure Lane
	Partially	Subsea7
D. Do the EISs identify CIs for the planning, implantation, operation, and deactivation phases?	Yes	-
	No	Odebrecht; Melport; Infrastructure Lane
	Partially	Subsea7; PPCT
E. Are the CIs described in qualitative terms? If yes, how?	Yes	-
	No	Odebrecht; Melport; Infrastructure Lane
	Partially	Subsea7, PPCT

Criterion	*Criteria assessment*	*Projects*
F. Are the CIs described in quantitative terms (magnitude prediction)?	Yes	-
	No	PPCT; Odebrecht; Melport; Infrastructure Lane, and Subsea7
	Partially	-
G. Is the methodology used to identify and assess CIs described and applied?	Yes	-
	No	Odebrecht; Melport; Infrastructure Lane
	Partially	PPCT; Subsea7
H. Are the CI study limitations identified and described?	Yes	-
	No	PPCT; Subsea7; Odebrecht; Melport; Infrastructure Lane
	Partially	-

Source: The authors (2020).

CRITERION A.

The two TRs that point out the need to consider the CIs, namely the Melport and Infrastructure Lane projects, were developed by the Paraná Environmental Institute (*Instituto Ambiental do Paraná*, IAP). The highway TR was developed based on Resolution No. 46/2015 of the State Department of the Environment (*Secretaria Estadual do Meio Ambiente*, Sema), which establishes the "requirements, definitions, criteria, guidelines, and administrative procedures of Environmental Licensing and Environmental Regularization of land road projects, both public and private, to be performed in the State of Paraná".

The TRs of the Melport and Infrastructure Lane MDPs have similar contents; in the fourth paragraph of the introduction, they state "positive and negative impacts, both direct and indirect; primary and secondary; short, medium and long term; cyclic, cumulative and synergistic [...]". In their respective summaries, they describe that the Chapter on "Environmental Impact Assessment" must identify and assess the environmental impacts considering "each of the natural environment components addressed in the environmental diagnosis and the various impact factors and their time of incidence (time frame), as well as an integrated analysis of these factors, their synergism or attenuation". The other two TRs analyzed, namely the 3P Porto Pontal and Subsea7 projects, were developed by Ibama and did not meet this criterion.

CRITERION B.

Four EISs met this criterion, and only the EIS of the Odebrecht project did not meet it. In the 3P Porto Pontal EIS (related to the PPCT), the word "cumulative" appears once; "synergy" 32 times, and "synergistic" 93 times. "Synergy" appears as an attribute of the impact assessment matrix concerning the presence or absence of specific impacts.

The Subsea7 EIS mentions the following terms: "synergy" 52 times and "synergistic" eight times. In this case, the word "synergy" appears as an attribute of the impact matrix, similar to the PPCT project EIS. That explains the number of mentions.

On the other hand, the Melport EIS employs the term "cumulative" once, "synergy" twice, and "synergistic" once. The terms "Synergy" and "cumulativeness" do not appear in the context of impact assessment. This specific study considers other projects in the area and their importance for impact assessment, as described here: "Potential conflicts regarding distinct uses of coastal water": "the synergistic and cumulative effect of the various projects planned and being implemented in the region

led to the development of compatible and complementary activities therein, often in opposition to those that previously existed" (ENVEX; 2014, p. 1162).

The Infrastructure Lane EIS mentions the term "synergy" and "synergistic" both once, as follows:

> The impacts detected in the matrix composed by leveraging Impactful Actions x Impacted Environmental Factors were described below, as per means of occurrence (quantitatively, whenever possible); project phase in which they are expected to occur; their potential synergy to other actions that may lead to the emergence and/or aggravation of other impacts (ENGEMIN, 2016, p. 4)

The term "synergistic" is employed to refer to the relationship between impactful factors, considering that "when environmental impacts occur on a specific factor and are rarely restricted to that factor, usually causing a synergistic effect on other factors" (ENGEMIN, 2016 p. 4).

CRITERION C.

The 3P Porto Pontal, Odebrecht, Melport, and Infrastructure Lane EISs include no definitions. The Subsea7 EIS defines "synergy": "an impact is considered synergistic when it is directly related to another and can increase its positive or negative effect. When there is no such possibility, the impact is classified as non-synergistic" (AAT, 2009, p.1103). No definitions of the terms "cumulative impacts" and "cumulativeness" were found. This criterion was considered partially met given the following, in which there is some approximation to the aforementioned:

> Synergistic: concerning other impacts, i.e., whether the association of the impact under analysis with others can increase its positive or negative effect; Non-synergistic: when there is no mutual relationship with other impacts. An example of a synergistic impact would be the deposition of sediments due to soil loss from erosive processes (AAT, 2009, p. 1101).

CRITERION D.

The 3P Porto Pontal and Subsea7 EISs had similar EIA approaches. In both cases, "synergy" was employed as an attribute of impact assessment and classification, thereby pointing out the synergistic aspect of the impacts of each phase (which, in turn, would be triggered based on the presence or absence of synergy) so this criterion was considered partially met. The 3P Porto Pontal EIS does not define "synergy" but lists it as an attribute to be assessed in each phase.

Three EISs (Odebrecht, Melport, and Infrastructure Lane) did not identify CIs in any of the phases and do not consider "synergy" and "cumulativeness" as impact attributes. For the phases assessed in the studies, the Infrastructure Lane EIS encompassed the Implantation and Operation phases; Melport included Implantation, Operation, and Deactivation; Odebrecht: Planning and Installation and; Subsea7 and 3P Porto Pontal considered all phases, except deactivation.

CRITERION E.

The 3P Porto Pontal project EIS includes a qualitative description of 16 environmental impacts after identifying the synergy attribute in the phase and between impacts (see examples in Table 4). Some negative impacts in the same phase were not considered synergistic: 1. Material and moral damages from displacing the population living in the affected area; 2. Increased risk of accidents on highway BR 277: "This has no present synergy with other impacts that are considered meaningful at this phase" (AMB, 2007, p. 98); 3. Health issues due to the increase in atmospheric pollutants; 4. Health issues and

other problems resulting from increased noise on state highway PR 412; 5. Damage to the structure of buildings near state highway PR 412 due to increased truck traffic; 6. Increased risk of accidents on highway BR 277; 7. Inhibition of new investments in tourism due to port activities: "This impact has no present synergies with other impacts planned for this phase" (AMB, 2007, p. 9). The synergy between phases was not assessed, only between impacts from the same phase.

Table 4 | Examples of environmental impacts listed and the qualitative descriptions of the ones considered as having synergy in the 3P Porto Pontal EIS

	Impact (Nature): Description
1	The worsening quality of life due to insufficient basic infrastructure and public services (N): "It has synergy with the inhibition of the influx of tourists, insofar as the worsening of services will discourage them from choosing Pontal do Paraná as a leisure destination; in turn, that may further worsen the situation given the loss of resources they were to invest" (p. 162)
2	An increase in public safety issues (N): "But there would be synergy with the inhibition of tourist influx to the municipality, in the sense that it would, in part, motivate, and, in turn, foment poverty and social disintegration, due to the decrease in sources of income." (p. 163)
3	Increase in prostitution (N): "Synergy with the potential inhibition of tourist influx; it could be higher, as it might add to the problem" (p. 163)

Key: (N) Negative Impact.

Source: The authors, based on the 3P Porto Pontal MDP EIS.

The Subsea7 EIS considered synergy an attribute. For example: Impact– Dispersion of noise pollution; Attribute–Synergy with other impacts/risks; Qualification–Increased edge effect in areas adjacent to the affected area; disturbances to terrestrial fauna in general due to noise emission; alterations in habitat use by medium and large mammal species; displacement and disturbances to aquatic fauna.

Other MDP EISs (Odebrecht, Melport, and Infrastructure Lane) did not meet this criterion.

CRITERION F.

The 3P Porto Pontal, Odebrecht, Melport, Infrastructure Lane, and Subsea7 EISs did not meet this criterion. The Subsea7 EIS used weights and attributes to assess the importance of the impact, which did not necessarily affect the ability to predict the magnitude of the impact. The weight attributed to synergy was as follows: 1 – not synergistic; 3 - synergistic. This was the methodology to define the value and importance of the environmental impact: "VALUE = (NATURE) X (1.0 X IMPORTANCE) + (0.9 X PROBABILITY OF OCCURRING) + (0.8 X SCOPE) + (0.7 X SYNERGY)".

CRITERION G.

The Subsea7 EIS considered the synergy attribute and described the methodology used to identify impact synergy. According to the EIS, presence and absence were based on whether the impact had a direct relationship with and consequently increased another one, regardless of it being positive or negative (see the transcript in criterion D). Furthermore, "when the impact is synergistic, the other impacts that may be increased must be mentioned" (AAT, 2009, p. 1101).

Despite including the synergy attribute, 3P Porto Pontal did not present a cohesive assessment methodology. Still, it mentions that "to determine whether an impact is synergistic or not and how relevant that may be, each impact was pondered in relation to others in the same phase," as seen in Table 4 of criterion E.

The Odebrecht, Melport, and Infrastructure Lane EIS did not meet this criterion since the CIs were not identified in the evaluation process.

CRITERION H.

None of the studies met this criterion. The Melport MDP mentions other development projects in the area but raises no uncertainties regarding the CIs.

The two TRs that demanded considering CIs did not describe a methodology to assess these CIs, which highlights the context shown by Barros and Pereira (2019) and Montaño *et al*. (2014), according to whom CIs are unduly taken into consideration during the environmental licensing process, leading to poor results in the EIA due to the lack of adequate technical guidelines. In addition, given that the same environmental agency is responsible for both TRs, the documents are standardized, even though the projects encompass significantly different activities. The problem is even more aggravating in the case of the Infrastructure Lane, in which seven different activities are aggregated in the same project and licensing process. During an analysis of the pressure-estate-response for a CIA of projects in the State of Minas Gerais, Neri *et al*. (2016, p. 296) state that the broad and general format of TRs for EISs is one of the reasons behind data inconsistency or unavailability.

From a technical point of view, the results showed that the TRs are guided by Conama Resolution 1/86, which recommends considering the impact's cumulative and synergistic "properties." The TRs that suggest considering the CIs during the assessment follow this same guideline. These studies reflect the guidelines from Conama and the environmental agency that developed the TR. Sánchez (2020) points out a common misconception about what is expected from a CIA. For the author, "assessing cumulative impacts is not the same as indicating in an EIS whether an impact has 'cumulative or synergistic properties', which is a common practice in Brazil," and the cases analyzed to prove that. The inconsistency and uncertainty from the onset of the environmental licensing process (as seen in the TRs) permeate the precariousness of impact studies and compromise the seriousness and rigour of CI assessments. In this sense, Siqueira-Gay *et al.* (2019) highlight that "Environmental Impact Studies need detailed guidelines to improve potential impact interaction analyses," drawing particular attention to the development of TRs. That demonstrates the gap between the theoretical-conceptual, scientific works and EIS's practice and professional application, as Morgan (2012) highlighted. So, it is worth noting that although synergism and attenuation are related to CIs, these terms are used as an attribute linked to the impact's property.

Regarding The PPCT project, in addition to not including recommendations from the environmental agency to consider the cumulative impacts, it has been at the centre of legal battles. Moreover, the entrepreneur attempted to run in the mayoral elections of Pontal do Paraná in 2020 with the motto "The Pontal We Want," bringing the works on the new port and highway (the New Infrastructure Lane) to the forefront of his campaign. Later, according to news reports, the businessman withdrew his candidacy in response to a Federal Police operation that "targeted him amidst investigations of irregularities for granting of an environmental license to Porto Pontal Paraná Importação e Exportação SA" (REVISTA OESTE, 2020). According to the news published in G1, "the businessman is under investigation by the Federal Police and is suspected of paying over BRL 1 million in bribe to obtain an environmental license for a new port in Pontal do Paraná" (G1, 2020).

However, the Odebrecht case highlights the need for the State of Paraná to establish a database that facilitates access to public environmental information and overcomes obstacles to scientific development, thereby improving political and professional practices. On the topic of CIAs, authors like Foley *et al*. (2017), Murray *et al.* (2014) and Olagunju and Gunn (2015) note the difficult access or lack of data as obstacles to developing this science. Foley *et al.* (2017) go one step further and identify

the problem as an investment opportunity, given the need for databases, tools, and regional models capable of aligning science, policies, and practice.

Regarding the presence and absence of terms in the EIAs, the Odebrecht project did not meet this criterion. In the other four studies, "synergy" or "synergistic" were more frequently used as attributes of the impact matrix that defined only presence and absence. As Barros and Pereira (2019) and Montaño *et al*. (2014) highlight, CIs are treated inadequately, and there is severe confusion regarding the terms used. Barros and Pereira (2019) identified that "cumulativeness was wrongly treated as a property of synergism." Similarly, it was noted that the EIS indicated synergy as an impact-related attribute, as aforementioned in Sánchez (2020). Four projects did not include term definitions. Two (namely the Infrastructure Lane and Melport EISs) included demands in the TRs to consider the CIs during their technical impact assessment studies.

The CIs in the planning, implantation, operation, and deactivation phases were not considered in three EISs (Melport, Odebrecht, and Infrastructure Lane). The PPCT and Subsea7 EISs use the term "synergy" as an impact attribute when related to others in their respective phases; this phase-based approach to CIs partially met this criterion. The lack of definitions and methodology fosters confusion when synergy is used as an attribute. That is corroborated by Barros and Pereira (2019) and is considered customary negligence that hinders environmental studies. In the specific case of Odebrecht, impact assessment focused on the planning and installation phases and did not include the operation phase; the justification for this is that the facilities had been previously used for other industrial activities. That raises concerns about the lack of CI analysis and a historical and spatial benchmark (OLAGUNJU; GUNN, 2015; SPALING, 1994) of impacts that have already been left on the environment due to activities done in the 1980s, the deactivation process and the current State, after years of ecosystem recovery. The latter is an essential difference in a proper CIA, where the stages are primarily based on selecting important Social and Environmental Components (SEC) and their status, unlike the EIA, which mainly focuses on the activity/impact (SÁNCHEZ, 2020).

The qualitative and quantitative approaches of the CIs proved to be lacking. There was no analysis between projects, and although the results show a similar synergy approach in the Subsea7 and PPCT MDPs, this study consisted of descriptive analysis without paying attention to space and time scales and presenting a gap between essential phases of cumulative environmental change. The Subsea7 project was the only exception because it quantified the synergy attribute to define impact magnitude and included the methodology. Despite this, it should be noted that mentioning this synergy attribute is not aligned with the CI approach advocated by Spaling (1994); therefore, that study is not enough to identify and assess cumulative impacts. That methodology was not present in the other EISs, nor were any uncertainties concerning CIs. Although this research is limited to five projected projects from a single municipality on the coast of Paraná, this research shows and reinforces that CIs are non-existent or insufficiently addressed in TRs and EISs that are part of the CIA review process, as argued by Montaño *et al.* (2014) and Neri *et al.* (2016).

When questioning the technocracy surrounding the CIA system and the environmental licensing process, Fase *et al*. (2011) suggest that the EIS methods employed in EISs "snatched by the economic interests involved in the project and in the repeated development of formally standardized and socially void impact studies." That is based on the qualitative description of some impacts considered to be synergistic in the 3P Porto Pontal EIS, e.g., 1. Increased prostitution; 2. The worsening quality of life due to insufficient basic infrastructure and public services; and 3. Increase in public safety issues, which interacts with 4. Inhibition of tourist influx. With this in mind, how will the State, corporate agents, and the local population face these issues resulting from installing a new industrial port complex in the municipality? That question remains unanswered, given that the current format of impact assessment is lacking, inefficient, and does not analyze the evident interaction between these four impacts, for instance. Furthermore, it does not consider the historical and future condition of the affected SECs and the interactions of impacts between projects (SÁNCHEZ, 2020), especially considering that the

social and spatial occupation of the Paranaguá Estuarine Complex already meets the criteria for high environmental impact due to the Paranaguá and Antonina Port and other industrial activities (ABRAHÃO and CANEPARO, 2014).

Bronz (2013) points out the business discourse strategy that claims "the State is not me" when the implantation of MDPs causes and increases negative social and environmental consequences. In this case, new questions arise from the institutionalized State's resilience to face the problems caused by these economic vectors. Guzmão (2010, p. 35) highlighted that "we must ask whether these agents–who are in direct contact with new emerging pressures and the immobilizing deficiencies of old–will be able to act strategically".

Finally, the EIA examination process of individual projects was not considered robust enough to analyze CIs. That is not far from other scientific findings. As Neri *et al*. (2016) suggested, despite confirming the need to perform CIAs in cases like Pontal do Paraná, "the approaches and methods commonly applied to the environmental impact assessment of an individual project might not be adequate." The difficulties and limitations are even harsher when considering simultaneous, spatially concentrated projects from different proponents and various typologies. Therefore, the present article highlights this complex and uncertain scenario, which covers how space appropriation by the set of projects will trigger in the short, medium, and long term, significantly affecting the most vulnerable coastal communities and essential natural and cultural environments.

5 FINAL CONSIDERATIONS

The objective of analyzing whether and how TRs and EISs of the major development projects in the Pontal do Paraná Industrial Port Complex assess cumulative impacts was achieved. However, this first approach was limited to the projects' negotiations and did not include other sources of impact, e.g., natural events. Another limitation was its local approach, which was restricted to the region. With this in mind, the most noteworthy points are as follows:

1. The lacking CI approach in which the CIA was conceived has been widely investigated in the literature. That adds to the numerous complaints about how the decision-making processes around Major Development Projects are carried out and how they are mostly limited to reproducing public approval of the enterprise. The legal dispute and investigation involving the purchase of an environmental license for Porto Pontal further aggravate this scenario.

2. Despite receiving the licenses, the MDPs linked to the IPC lack sufficient CI analyses. That occurs from the initial process of environmental licensing with the underwhelming development of the TRs, which are still far from scientific discussions in the field of impact assessment, proving to be ineffective in identifying and assessing CIs. A more robust impact assessment process focused on cumulative impacts, and their methodologies should consider the whole set of projects and territorial planning, not merely individual assessments alongside pre-approved projects. A potential solution would be using different impact assessments discussed and implemented worldwide, such as CIA, SEA, and IEA. The SEA and the IEA are already used for SHPs in the Amazon.

3. Individual granting of environmental licenses and the lack of an EIA process capable of addressing CIs raises serious concerns, given the potential of the projects in Pontal do Paraná to bring forth a context of uncertainty from a social and environmental perspective. This is evident in the case of territorial expropriation of a traditional fishing community (i.e., Ponta do Poço) and the risk imposed on two new cases (the Sambaqui

Indigenous Land and the Maciel Fishermen's Community, as shown in Figure 1). In addition to this tension from overlapping disputed territories, there is an increased risk of deforestation that might result in the loss of Atlantic Forest areas considered highly relevant for conserving biodiversity (MMA, 2018) and the culture and know-how of different ethnic groups that inhabit the region and engage with this fundamental biome.

4. Some limitations of this article include the lack of discussion around the dimension of power. Because of this, it is essential to reflect on how intrinsic issues of the modern colonial and capitalist system might still have a crucial role in democracy and how they permeate power relations in decision-making processes. Or, even with better cumulative impact assessment during the environmental licensing process, would power relations still be relevant in the final say of decision-making processes?

NOTES

1| Environmental licensing is part of the National Environmental Policy, Law No. 6938 of August 31st, 1981. Two Resolutions of the Brazilian National Environment Council [Conselho Nacional de Meio Ambiente, Conama] are important for understanding the applicability of EIA in Brazil: Resolution No. 1/1986, which deals with the criteria, definitions, responsibilities, general guidelines for using and implementing the EIA, and even the establishment of the Environmental Impact Study and Environmental Impact Report (EIS/EIR) and Resolution No. 237/1997, which provides an overview of environmental licensing procedures and criteria.

2| Currently, only the Techint facilities are still in place, but it is deactivated at the moment.

3| It was not possible to obtain the Terms of Reference (TR) of the Odebrecht MDP despite filing a formal application to Instituto Água e Terra (IAT) and a request to the Specialized Environment Support Group (Grupo de Apoio Especializado em Meio Ambiente, Gaema) of the Department of Public Prosecution of the State of Paraná.

4| Licensing phase at the time of consultation, in 2020.

5| The 2010 EIS is a request for additional information about the physical and biotic environment. The EIS itself explains which additional information was requested by the environmental agency, so the technical report requesting this additional information was excluded from the analysis. Furthermore, the additional EIS does not mention cumulative impacts, which are the focus of the present analysis.

6| The Odebrecht MDP Terms of Reference (TR) were not analyzed because they were not provided by the state environmental agency.

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A ausência de análise de impactos cumulativos no licenciamento ambiental do Complexo Industrial Portuário, Pontal do Paraná, litoral sul do Brasil

The lack of cumulative impact analysis in the environmental licensing of the Industrial Port Complex at Pontal do Paraná, on the southern coast of Brazil

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ARTICLE- VARIA

RESUMO

A Avaliação de Impacto Ambiental é um instrumento da política ambiental que surge como resposta às preocupações da sociedade sobre os impactos negativos dos empreendimentos e ao reconhecimento dos limites planetários. No Brasil, está inserido no processo administrativo do Licenciamento Ambiental, no qual fragilidades coexistem. Os Impactos Cumulativos (ICs), resultantes de múltiplas alterações decorrentes de intervenções (naturais ou antrópicas) concentradas espacial e temporalmente, corriqueiramente, recebem tratamento insuficiente. A instalação de um Complexo Industrial Portuário (CIP) no município de Pontal do Paraná está em fase de licenciamento ambiental. Este artigo objetivou verificar se e como os projetos do CIP avaliam os ICs por meio de análise documental dos Termos de Referência (TR) e Estudos de Impacto Ambiental (EIA) de cinco empreendimentos. Os resultados apontam que os TRs e EIAs *são insuficientes na análise dos* ICs. No âmbito político-procedimental, não há institucionalização para a prática de Análise de Impactos Cumulativos. Mesmo que ela ocorra, é imprescindível considerar o peso das relações de poder para aceitação pública de megaempreendimentos. Localmente, as incertezas sobre os ICs refletem cenários de insustentabilidade ambiental.

Palavras-chave: Avaliação de Impactos Cumulativos. Estudo de Impacto Ambiental. Planejamento Territorial. Floresta Atlântica.

ABSTRACT

The Environmental Impact Assessment is an environmental policy instrument developed as a response to societal concerns about the negative impacts of major development projects and the recognition of planetary boundaries. In Brazil, it is part of the environmental licensing process, which also encompasses various weak points. Cumulative Impacts (CIs) from multiple interventions (both natural or anthropic) across specific spaces and time frames are routinely dealt with poorly. The installation of an Industrial Port Complex (IPC) at Pontal do Paraná, a municipality on the south coast of Brazil, is currently undergoing an environmental licensing process. This article analyzes the Terms of Reference (TR) and Environmental Impact Studies (EIS) of five projects to verify if and how the IPC projects assess CIs. The results suggest that TRs and EISs provide insufficient to assess CIs. In the political-procedural sphere, there is no institutionalization for the practice of Cumulative Impact Analysis. Moreover, even if it is performed, it is essential to consider how power relations affect the public acceptance of mega-projects. Locally, uncertainty about CIs reflects into scenarios of environmental unsustainability.

Keywords: Cumulative Impact Assessment. Environmental Impact Study. Territorial Planning. Atlantic Forest.

1 INTRODUÇÃO

O campo de pesquisa e prática sobre os impactos cumulativos se encontra em estágio inicial no Brasil. Apesar disso, tem importância para orientar iniciativas de prevenção e enfrentamento dos problemas socioambientais (DIBO, 2018). Esse campo do conhecimento está alinhado à política de gestão ambiental preventiva dentro de um guarda-chuva central que é a Avaliação de Impacto Ambiental (AIA) (MORGAN, 2012). A AIA surge como uma resposta por parte dos governos e cientistas aos impactos da industrialização e seus efeitos na saúde humana e ambiental. Essa abordagem técnico-institucional alinha-se a uma agenda do ambientalismo moderado, conhecida por modernização ecológica, em que os impasses entre os objetivos econômicos de desenvolvimento e as aspirações ambientais seriam superados por esse arcabouço (MILANEZ, 2009; PI PUIG, 2019).

No Brasil, o instrumento técnico de AIA está inserido no processo administrativo do Licenciamento Ambiental[1] um dos mecanismos para autorização de implementação de empreendimentos e que integra a Política Nacional de Meio Ambiente (BRASIL, 1981). Assim, o processo de AIA corresponde a etapas voltadas para examinar o quão determinada proposta pode alterar as condições atuais do ambiente afetado e orientar a tomada de decisão no processo administrativo do licenciamento ambiental. Toda e qualquer atividade modificadora do meio ambiente está sujeita a autorização do órgão ambiental responsável por uma concessão trifásica de licença ambiental (Licença Prévia, de Instalação e de Operação) (SÁNCHEZ, 2020).

Os Grandes Projetos de Desenvolvimento (GPDs), foco deste artigo, são aqueles empreendimentos ligados, em sua maioria, à conversão do espaço ambiental em infraestruturas para extração de bens territoriais (p. ex. minério, produção agropecuária, energia elétrica e petróleo) e suporte logístico para o seu escoamento (estradas, portos, ferrovias, gasoduto, poliduto, etc.). Desde a década de 1970, esses projetos são regidos pela iniciativa privada (grandes corporações) e pela atuação do estado-facilitador por meio das macropolíticas setoriais, planejamentos e ordenamentos alinhados para a entrada dos projetos e financiamento por meio de planos, programas e bancos multilaterais (BERNO DE ALMEIDA *et al.,* 2010; CASTRO, 2012; GUSMÃO, 2010; VAINER, 2007).

Aspectos político-procedimentais para aceitação dos GPDs chamam atenção de pesquisadores do campo da Ecologia Política por suas consequências socioambientais. Segundo Acselrad (2011) e Zhouri (2008), os GPDs atuam em um processo violento de expropriação de produtores familiares, artesanais,

camponeses e indígenas, que têm como base de vida e produção os bens naturais de uso comum. Os impactos dos projetos não são democráticos, o que significa que os riscos e incertezas são distribuídos de forma desigual e atingem populações já historicamente vulnerabilizadas. De acordo com Acselrad (2011), "planejadores ou investidores desses projetos tendem a minimizar a presença de determinadas populações nas áreas onde pretendem se instalar", desde a concepção do planejamento territorial até o "desconhecimento ativo" relacionados aos impactos dos projetos em licenciamento nos grupos atingidos (FASE *et al.*, 2011, p. 26).

Não obstante, Acselrad (2011) considera que nenhum projeto de desenvolvimento deve ser construído sob pretexto de progresso levando sacrifícios aos grupos sociais e custos incalculáveis para o meio ambiente. Na contramão, a AIA, como principal instrumento para aprovação dos Grandes Projetos, reproduz métodos convencionais desde o processo de separação entre aspectos biofísicos, dimensões sociopolíticas e culturais até a difícil discussão sobre a relação entre equidade ambiental, desigualdade social e ambiental (LEROY; ACSELRAD, 2011).

Fase, Ettern e Ippur (2011) e Zhouri (2008) pontuam que os EIA/Rimas têm sido convertidos mais em uma função reativa de aceitação pública dos projetos diante do âmbito social e político do que de função de mobilização proativa acerca dos impactos ambientais e de base assertiva para tomada de decisão. Incorporam-se a esses contextos inúmeras batalhas e disputas judiciais justificadas pela falta de cumprimento de obrigações, divergências técnicas, competência do licenciamento e falta e/ou insuficiência de participação popular. O Ministério Público (MP) da União e o dos Estados têm realizado inúmeras intervenções decorrentes da falta de transparência e de conduta que reverberam frequentes processos de judicialização que marcam o licenciamento ambiental no Brasil (HOFMANN, 2015, p. 41; 57-59).

No processo de AIA, os Impactos Cumulativos (ICs) não recebem tratamento suficiente ou, muitas vezes, são desconsiderados, e a comunidade científica, grupos e movimentos sociais vêm alertando sua criticidade e ausência. Os ICs são entendidos como o resultado de um conjunto de ações concentradas espacial e temporalmente, sejam estas antrópicas ou naturais, que atuam na modificação substancial dos sistemas socioambientais (OLAGUNJU; GUNN, 2015). Na mesma direção, Sánchez (2020, p. 280) define que "os impactos cumulativos são os efeitos totais sobre um recurso ambiental, ecossistema ou comunidade, independentemente da origem das ações causadoras".

Nesse contexto, emerge uma discussão sobre a significância de pequenos empreendimentos e os seus impactos, visto que uma série de impactos analisados individualmente podem ser considerados como insignificantes, mas que, com vistas aos impactos cumulativos, essa avaliação pode constatar um dano irreparável. De forma semelhante, projetos analisados individualmente podem apresentar impactos significativamente menores do que quando vistos concentrados espacialmente e conectados ao longo do tempo (BARROS; PEREIRA, 2019; DUARTE *et al*., 2017; MONTAÑO *et al.*, 2014; SÁNCHEZ, 2020). É nesse viés que Siqueira-Gay *et al.* (2019) corroboram a discussão do potencial de impactos significativos com a instalação de um conjunto de pequenas centrais hidrelétricas (PCHs), especialmente na região Amazônica, e a negligência dos impactos cumulativos: "quando o pequeno não é belo".

No Brasil, institucionalmente, não há regulamentação própria para uma Avaliação de Impactos Cumulativos (AIC). A Resolução do Conama n°1/1986 sugere/recomenda que se considere, na análise dos impactos e suas alternativas, a descrição de "suas propriedades cumulativas e sinérgicas; a distribuição dos ônus e benefícios sociais" (CONAMA, 1986). Apesar dessa recomendação de análise dos ICs no contexto da AIA, outros instrumentos, como a Avaliação Ambiental Estratégica (AAE) e a Avaliação Ambiental Integrada (AAI), embora não regulamentados por lei, têm sido reivindicados em situações de planejamento para bacias hidrográficas, especialmente para o mesmo tipo de empreendimento, a exemplo das hidrelétricas e PCHs localizadas na região amazônica (GALLARDO *et al.,* 2017.; SIQUEIRA-GAY *et al.,* 2019).

O licenciamento ambiental de grandes empreendimentos vem sendo acompanhado por tensões e disputas, além de um processo sistemático de desmonte e desregulação ambiental no Brasil (BARCELOS, 2020; ZHOURI, 2008). Nos âmbitos regional e local, as fronteiras de exploração desse modelo de desenvolvimento fundado nos GPDs avançam para os territórios em ritmo acelerado (ALÍER, 2007). No estado do Paraná, localizado na Região Sul do Brasil, a formação econômica tem se reproduzido pela lógica da competitividade e redes de integração do agronegócio. Assim, as regiões estão organizadas tanto pela produção primária (soja, café e energia elétrica) como pelo escoamento por meio do suporte logístico-portuário (SILVA; GONÇALVES, 2019). A região litorânea do estado caracteriza-se, nesse último contexto, pela presença do nó portuário, Porto de Paranaguá e de Antonina, localizados no Complexo Estuarino de Paranaguá. A atividade portuária-industrial tem se expandido nas últimas décadas, o que tem refletido na conversão das formas de ocupação e uso do espaço dos territórios para acumulação do capital (ABRAHÃO; CANEPARO, 2014; CUNHA, 2018).

O caso em tela destaca o município de Pontal do Paraná e a intenção de conversão do espaço territorial atualmente regido majoritariamente pelo setor turístico-praiano fortemente marcado pela presença de comunidades tradicionais pesqueiras (PIERRI *et al.,* 2006) para o portuário-industrial (CUNHA, 2018). Considerando, portanto, o conjunto de cinco GPDs em licenciamento que constituem o Complexo Industrial Portuário (CIP) de Pontal do Paraná, objetiva-se analisar se e como os Termos de Referência e os Estudos de Impacto Ambiental desses empreendimentos abordam os impactos cumulativos. Este artigo organiza-se da próxima seção sobre o contexto de Pontal do Paraná, os empreendimentos pleiteados e os territórios em disputa, na sequência, a metodologia utilizada, os resultados e suas discussões e, por fim, as considerações finais.

2 PONTAL DO PARANÁ: GRANDES PROJETOS DE DESENVOLVIMENTO E OS TERRITÓRIOS EM DISPUTA

O litoral do Paraná apresenta importante papel na conservação da natureza em função de suas potencialidades sociobiodiversas e da presença dos maiores remanescentes contínuos de Mata Atlântica (PDS LITORAL, 2019). Por outro lado, enfrenta graves problemas de vulnerabilidade social (AZEVEDO, 2016), política do abandono (TIEPOLO, 2016) e conflitos em relação ao planejamento para o território (CALDEIRA, 2018; CUNHA, 2018). Isso tem se refletido em contextos marcantes de disputas sobre a produção socioespacial acompanhadas por fluxos de acumulação do capital em detrimento das vocações socioculturais e naturais, como é o caso de Pontal do Paraná (AZEVEDO, 2016; CALDEIRA, 2018; CUNHA, 2018; TIEPOLO, 2016).

O processo de urbanização do município de Pontal do Paraná teve ligação direta com o setor empresarial, envolvendo um contrato de concessão de terras públicas para a empresa denominada “Balneária Pontal do Sul” em 1950. O contexto enfatiza o histórico de privatização de terras públicas que acaba sendo responsável pelo desencadeamento de conflitos territoriais com comunidades pesqueiras e contradições envolvendo o ordenamento territorial do município (CUNHA, 2018).

Pontal do Paraná é um município principalmente praiano-turístico (IPARDES, 2022). Foi a partir da década de 1980, que ocorreram as primeiras investidas de empreendimentos portuários e petrolíferos (Tenenge, CBC representante da Mitsubishi Motors no Brasil, Techint e FEM – Projetos, Construções e Montagens), mas ao longo dos anos seguintes essas iniciativas caíram em declínio acarretando na desativação dos empreendimentos (CUNHA, 2018). Entre os municípios do litoral sul, é o que apresenta maior crescimento populacional, especialmente no cenário de instalação de novos empreendimentos portuários e industriais. Estima-se que, em 2035, poderá chegar a mais que o dobro da população (cerca de 50 mil habitantes) em relação a 2010 (20.920 habitantes) (PDS LITORAL, 2019). No que tange à vulnerabilidade social, segundo Azevedo (2016), um setor rural com 177 residentes encontra-se em situação de vulnerabilidade muito alta. Para a autora: “cerca de 38% vivem em áreas de média vulnerabilidade social e pouco mais de 0,5% em um setor de alta vulnerabilidade, na área que

corresponde à comunidade pesqueira do Maciel" (AZEVEDO, 2016, p. 114). Dados de 2008 mostram que a atividade pesqueira representava o envolvimento de 2% da população de Pontal do Paraná, chegando a aproximadamente 400 pessoas com registro na Colônia de Pescadores, distribuídos em 13 localidades no município (CALDEIRA; PIERRI, 2014). Destaca-se também a presença de povos originários Guaranis, na Terra Indígena Sambaqui, área demarcada, mas ainda não titulada (INSTITUTO SOCIOAMBIENTAL, 2020).

O Complexo Industrial Portuário proposto para Pontal do Paraná prevê a instalação de cinco novos empreendimentos[2], todos com exigência de EIA/Rima para o licenciamento ambiental. Os empreendimentos são: A. 3P Porto Pontal, também denominado Terminal de Contêineres Pontal do Paraná (TCPP); B. Melport Terminais Marítimos; C. Odebrecht; D. Subsea7; e E. Nova Faixa de Infraestrutura. Todos localizados nas proximidades do Rio Guaraguaçu, sendo que quatro deles situados em frente à Terra Indígena da Ilha da Cotinga. O empreendimento D sobrepõe-se à TI Sambaqui e a outras 15 localidades de comunidades tradicionais, em sua maioria de pescadores artesanais, que serão afetadas direta ou indiretamente (Figura 1).

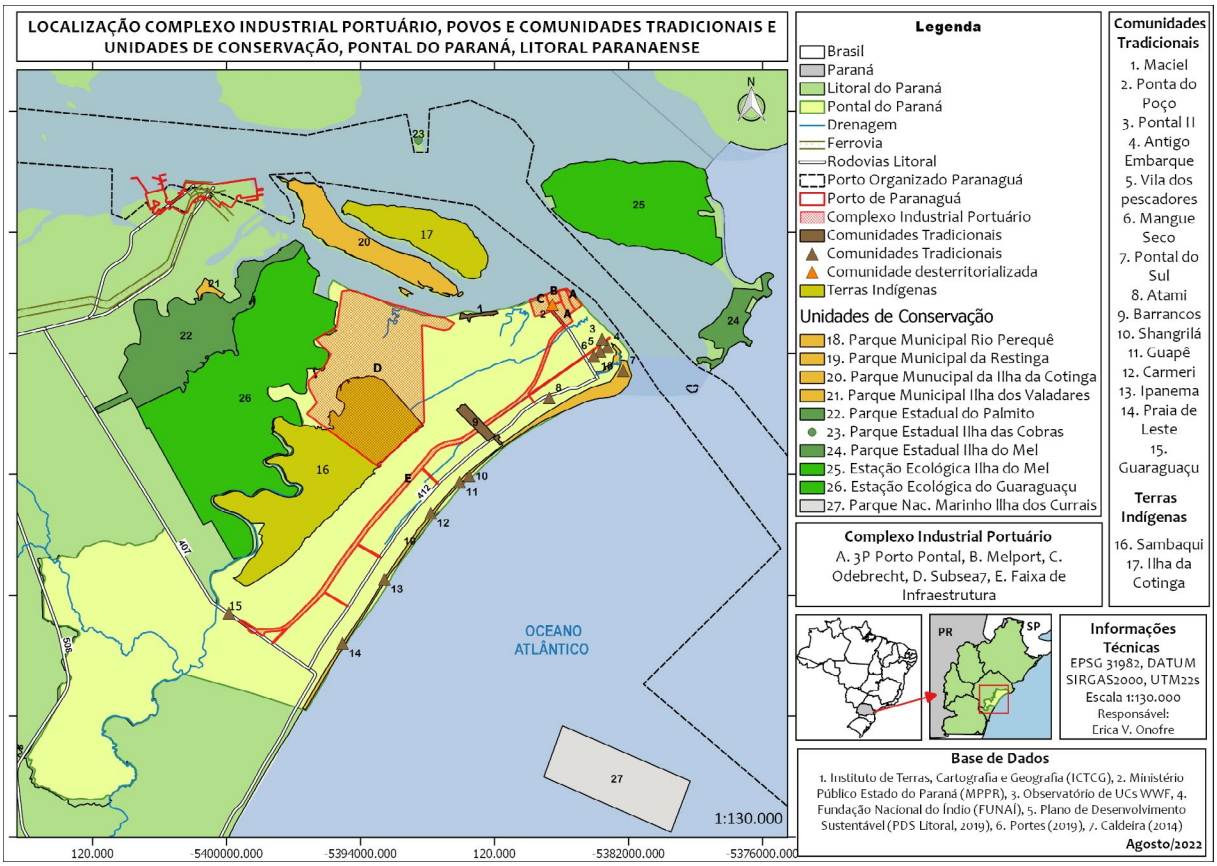

Figura 1 | Localização do Complexo Industrial Portuário, Povos e Comunidades Tradicionais e Unidades de Conservação, Pontal do Paraná, Litoral Paranaense

Fonte: Autoras (2021).

3 METODOLOGIA

O procedimento de análise documental adotado é composto por três etapas: (1) contextualização temática; (2) identificação de origem, contexto histórico da produção do documento, autoria, objetivos e público-alvo; e (3) esquematização e análise do documento (LÉTOURNEAU, 2011). As etapas 1, 2 e parte da 3 acerca da esquematização fazem parte do material mais robusto em que se inicia o processo de consulta aos documentos. Nesse sentido, para o presente artigo, a contextualização da

temática foi apresentada na própria fundamentação do que é o licenciamento ambiental, AIA e os seus procedimentos. Logo, a etapa dois está incluída na Tabela 1 abaixo. A esquematização do documento parte da seleção de quais itens foram analisados e como, expostos na sequência da Tabela 1. Foram analisados quatro Termos de Referência[3] (TRs) e os cinco estudos de impacto ambiental dos cinco GPDs em licenciamento em Pontal do Paraná (Tabela 1), os quais foram obtidos com o auxílio do Observatório Costeiro (OC2) do Litoral do Paraná e de pesquisadores vinculados à Pós-Graduação em Geografia da Universidade Federal do Paraná. O acesso aos documentos foi realizado no segundo semestre de 2019 e a consulta entre 2019 e 2021.

Tabela 1 | Caracterização dos empreendimentos em licenciamento em Pontal do Paraná e documentos analisados

Documento	*Empreendedor*	*Órgão Licenciador / Fase da Licença*[4]	*Ano do EIA*	*Iniciativa*
TR e EIA – 3P Porto Pontal (3P)	Porto Pontal Paraná Importação e Exportação Ltda.	Ibama / LI condicionada à construção de uma nova rodovia.	2007 e 2010[5]	Privada
Caracterização: Projeto prevê "estruturas de acostagem, áreas de armazenagens descobertas e vias internas, armazéns e estruturas administrativas e de apoio às operações" (AMB PLANEJAMENTO AMBIENTAL, 2007). Projeto estimado em R$ 1.500.000.000,00.				
TR e EIA – Melport Terminais Marítimos Ltda. (MTM)	Melport Terminais Marítimos Ltda	IAP / LP emitida	2014	Privada
Caracterização: Terminal multifuncional com parque para tancagem de granéis líquidos, armazém de cargas gerais, pátio de contêineres e apoio logístico Offshore (ENVEX et al., 2014). Projeto estimado em R$ 100.000.000,00.				
TR e EIA – Faixa de Infraestrutura (FI)	DER (Departamento de Estradas de Rodagem do Estado do Paraná)	IAP / LI (judicializada pelo Ministério Público do Paraná – MP-PR)	2016	Pública
Caracterização: A obra prevê implantação de nova rodovia (Via Arterial) e de ligações desta à PR-412 (quatro vias coletoras); ampliação e retificação do canal Dnos existente; implantação de ferrovia; implantação de gasoduto; implantação de linha de transmissão e implantação de dutos de saneamento (ENGEMIN, 2016). Projeto estimado em R$ 270.000.000,00.				
EIA[6] – Obras de readequação de cais e dragagem – Odebrecht (ODB)	Construtora Norberto Odebrecht S.A.	IAP / Licenciamento retirado após Operação Lava Jato	2011	Privada
Caracterização: A obra prevê a readequação de cais para atracação de navios e dragagem de aprofundamento do Canal da Galheta. Projeto estimado em R$ 15.000.000,00 (MRS ESTUDOS AMBIENTAIS, 2011).				
TR e EIA – Base de soldagem Subsea7 do Brasil (SS7)	Subsea7 do Brasil Serviços Ltda.	IAP / LP concedida e cancelada	2009	Privada
Caracterização: Empresa norueguesa de construção e engenharia de bases submarinas para exploração de petróleo e gás. Projeto estimado em R$ 103.000.000,00 (AAT, 2009).				

Fonte: Autoras, de acordo com os EIAs, Cunha (2018), Ibama (2020) e Pigosso (2018).

Para verificar se os TRs e os EIAs abordam ou não os impactos cumulativos, foi realizada a busca pelas palavras-chave "cumulativo(a)", "cumulatividade", "sinergia" e "sinérgico" no capítulo de prognóstico ambiental em função de ser um passo posterior ao diagnóstico ambiental, este último responsável por dar base para previsão, análise dos impactos e propostas de medidas mitigadoras e/ou compensatórias.

Como explica Sánchez (2020), o diagnóstico ambiental é um passo anterior ao prognóstico ambiental. O diagnóstico permite "obtenção e a organização das informações necessárias à identificação e a previsão dos impactos", ou seja, fornece base para análise dos impactos, realizada no próximo passo que é o prognóstico ambiental (SÁNCHEZ, 2020, p. 182). Portanto, como o foco de análise são

os impactos avaliados, entende-se que o capítulo selecionado é o mais pertinente para análise. A seguir foi realizada a leitura do conteúdo indicado pela palavra-chave, a fim de analisar como foram abordados os impactos cumulativos, correspondendo aos critérios adotados para análise do conteúdo baseado em Cooper e Sheate (2002), adaptado por Barros e Pereira (2019), descritos na Tabela 2. Para cada critério foi analisado se o documento atende (sim), não atende (não) ou atende parcialmente (parcialmente) aquele critério.

Tabela 2 | Critérios para análise documental

A. O Termo de Referência solicita considerar os impactos cumulativos**?
B. Os EIAs mencionam os termos "cumulativo(a)", "cumulatividade", "sinergia"* ou "sinérgico"*?
C. Os EIAs definem "impactos ambientais cumulativos" ou "cumulatividade" ou "sinergia"*?
D. Os EIAs identificam os IC para as fases de planejamento*, implantação, operação e desativação* da atividade?
E. Os IC são qualitativamente descritos? Se sim, como?*
F. Os IC são quantitativamente descritos (previsão da magnitude)?
G. A metodologia para identificar e avaliar os IC é descrita e aplicada?
H. As incertezas resultantes das limitações do estudo dos IC são identificadas e descritas?

Fonte: Elaborada e adaptada pela autora de acordo com Cooper e Sheate (2002) adaptada por Barros e Pereira (2019).
*Legenda: **Critério incluído pelas autoras; *Complementações realizadas pelas autoras*

4 RESULTADOS E DISCUSSÃO

Quatro Termos de Referência (TRs) e cinco Estudos de Impacto Ambiental (EIAs) foram analisados. A partir dos critérios utilizados para análise documental, os TRs e EIAs analisados apresentaram os seguintes resultados (Tabela 3).

Tabela 3 | Atendimento aos critérios pelos TRs e EIAs dos GPDs analisados

Critério	*Resposta aos critérios*	*Empreendimentos*
A. O Termo de Referência solicita considerar os ICs?	Sim	Melport e Faixa de Infraestrutura
	Não	TCPP; Subsea7
	Parcialmente	-
B. Os EIAs mencionam os termos "cumulativo(a)", "cumulatividade", "sinergia" e "sinérgico"?	Sim	TCPP; Subsea7; Melport; Faixa de Infraestrutura
	Não	Odebrecht
	Parcialmente	-
C. Os EIAs definem "impactos ambientais cumulativos" ou "cumulatividade" ou "sinergia"?	Sim	-
	Não	TCPP; Odebrecht; Melport; Faixa de Infraestrutura
	Parcialmente	Subsea7
D. Os EIAs identificam os ICs para as fases de planejamento, implantação, operação e desativação da atividade?	Sim	-
	Não	Odebrecht; Melport; Faixa de Infraestrutura
	Parcialmente	Subsea7; TCPP
E. Os ICs são qualitativamente descritos? Se sim, como?	Sim	-
	Não	Odebrecht; Melport; Faixa de Infraestrutura
	Parcialmente	Subsea7, TCPP

Critério	*Resposta aos critérios*	*Empreendimentos*
F. Os ICs são quantitativamente descritos (previsão da magnitude)?	Sim	-
	Não	TCPP; Odebrecht; Melport; Faixa de Infraestrutura e Subsea7
	Parcialmente	
G. A metodologia para identificar e avaliar os ICs é descrita e aplicada?	Sim	-
	Não	Odebrecht; Melport; Faixa de Infraestrutura
	Parcialmente	TCPP; Subsea7
H. As incertezas resultantes das limitações do estudo dos ICs são identificadas e descritas?	Sim	-
	Não	TCPP; Subsea7; Odebrecht; Melport; Faixa de Infraestrutura
	Parcialmente	-

Fonte: Elaborada pelas autoras (2020).

CRITÉRIO A.

Os dois TRs que solicitaram considerar os ICs foram elaborados pelo Instituto Ambiental do Paraná (IAP), vinculados aos projetos da Melport e Faixa de Infraestrutura. O TR da rodovia foi elaborado a partir da Resolução n° 46/2015 da Secretaria Estadual de Meio Ambiente (Sema), que estabelece "requisitos, definições, critérios, diretrizes e procedimentos administrativos referentes ao Licenciamento Ambiental e Regularização Ambiental de empreendimentos viários terrestres, públicos e privados, a serem cumpridos no território do Estado do Paraná".

Os TRs dos GPDs Melport e Faixa de Infraestrutura apresentam conteúdos similares, de forma que, no quarto parágrafo da introdução, dispõem que devem ser "indicados os impactos positivos e negativos, diretos e indiretos; primários e secundários; imediatos, de médio e longo prazo; cíclicos, **cumulativos e sinérgicos** [...]". Na itemização, descrevem que o Capítulo de "Avaliação de Impactos Ambientais" deve identificar e avaliar os impactos ambientais considerando "cada um dos fatores componentes do meio natural abordados no diagnóstico ambiental e os diversos fatores de impacto e seus tempos de incidência (abrangência temporal), assim como a análise integrada desses fatores, **seu sinergismo ou atenuação**". Os outros dois TRs analisados, pertencentes aos empreendimentos 3P Porto Pontal e Subsea7 e elaborados pelo Ibama, não atenderam ao critério.

CRITÉRIO B.

Quatro EIAs atendem ao critério. Apenas o EIA referente ao empreendimento Odebrecht não atende. No **EIA pertencente ao 3P Porto Pontal (TCPP)**, a palavra "cumulativo" foi mencionada uma vez, "sinergia", 32 vezes e "sinérgico", 93 vezes. A sinergia foi acionada como atributo na matriz de avaliação de impacto marcando presença e ausência conforme a ocorrência no impacto.

O **EIA do empreendimento Subsea7** menciona os seguintes termos: "sinergia" com 52 menções e "sinérgico" com oito menções. Nesse caso, a palavra "sinergia" aparece como atributo da matriz de impacto, semelhante ao identificado no EIA do empreendimento TCPP. Isso explica a quantidade de citações encontradas.

Já **o EIA da Melport** apresenta uma menção ao termo "cumulativo", duas para "sinergia" e uma para "sinérgico". Não foram encontrados os termos "sinergia" e "cumulatividade" como atributo da avaliação de impactos. Notou-se que o estudo considera a presença de outros empreendimentos na área e, até

mesmo, a necessidade de considerar a presença desses na avaliação de impactos, conforme descrito no impacto de "Possibilidade de conflitos com relação aos diferentes usos da água costeira": "o efeito **sinérgico** e cumulativo dos diversos empreendimentos planejados e em implantação na região tem levado a que seja utilizada por atividades ao mesmo tempo compatíveis e complementares, muitas vezes contrapondo-se àquelas já existentes anteriormente" (ENVEX; 2014, p. 1162).

O **EIA da Faixa de Infraestrutura** apresenta uma menção ao termo "sinergia" e uma menção para "sinérgico", descritos da seguinte forma:

> Os impactos detectados na matriz constituída pela contraposição de Ações Impactantes x Fatores Ambientais Impactados foram a seguir descritos, buscando-se caracterizá-los em seu modo de ocorrência (sempre que possível, de forma quantitativa); fase do empreendimento em que se espera que venham a manifestar-se; sua possível **sinergia** em relação a outras ações que resultem em aparecimento e ou agravamento de outros impactos (ENGEMIN, 2016, p. 4)

O termo "sinérgico" foi mencionado para tratar da inter-relação entre os fatores impactantes, considerando que "quando ocorrem impactos ambientais sobre um determinado fator, raramente eles se restringem a esse fator, havendo, usualmente, um certo efeito **sinérgico** sobre outros fatores" (ENGEMIN, 2016, p. 4).

CRITÉRIO C.

Os EIAs dos empreendimentos 3P Porto Pontal, Odebrecht, Melport e Faixa de Infraestrutura não apresentam definição. O EIA do empreendimento **Subsea7** define "sinergia": "quando um impacto tem relação direta com outro e pode aumentar seu efeito, seja positivo ou negativo, é considerado sinérgico. Quando não há essa possibilidade, o impacto é classificado como não sinérgico" (AAT, 2009, p.1103). Não foram encontradas definições relacionadas aos termos "impactos cumulativos" e "cumulatividade". Apesar disso, considera-se que esse critério foi atendido parcialmente tendo em vista que o trecho extraído demonstra uma aproximação:

> **Sinérgico:** em relação a outros impactos, isto é, se a associação do impacto em análise com outros diagnosticados pode aumentar o seu efeito, seja positivo ou negativo; Não **sinérgico:** quando não ocorre relação mútua com outros impactos. Um exemplo de impacto **sinérgico** pode ser a deposição de sedimentos pela perda de solos por processos erosivos (AAT, 2009, p. 1101).

CRITÉRIO D.

Os EIAs dos empreendimentos 3P Porto Pontal e Subsea7 foram semelhantes em relação à abordagem nas AIAs. Notou-se que nos dois casos utilizaram sinergia como um atributo na avaliação e classificação do impacto e, com isso, foi apontado o caráter sinérgico dos impactos dentro de cada fase acionados quando havia presença e ausência de sinergia, por isso, constatou-se que o critério foi parcialmente atendido. O EIA do 3P Porto Pontal não define o que se entende por "sinergia", mas a considera como atributo a ser avaliado dentro de cada fase.

Três EIAs (Odebrecht, Melport e Faixa de Infraestrutura) não identificaram ICs em nenhuma das fases e não utilizam sinergia e cumulatividade como atributo de impacto. Sobre as fases avaliadas nos estudos, o EIA da Faixa de Infraestrutura avaliou as fases de Implantação e Operação; Melport considerou Implantação, Operação e Desativação; Odebrecht: Planejamento e Instalação; e Subsea7 e 3P Porto Pontal consideraram todas as fases, exceto a de desativação.

CRITÉRIO E.

O estudo do empreendimento 3P Porto Pontal apresenta uma descrição qualitativa de dezesseis (16) impactos ambientais quando identificado o atributo de sinergia dentro da fase e entre os impactos (ver exemplos na Tabela 4). Alguns impactos negativos de ocorrência na mesma fase não foram considerados sinérgicos, são eles: 1. Dano material e moral à população que morava na ADA devido à sua remoção; 2. Incremento de risco de acidentes na BR-277: "considera-se que não apresenta **sinergia** com outros impactos considerados significativos nesta fase" (AMB, 2007, p. 98); 3. Danos à saúde da população devido ao aumento de poluentes atmosféricos; 4. Danos à saúde e outros problemas decorrentes do aumento do ruído na PR-412; 5. Danos à estrutura das construções próximas à PR-412 devido ao aumento de tráfego de caminhões; 6. Incremento de risco de acidentes na BR-277; 7. Inibição de novos investimentos em turismo devido às atividades portuárias: "Este impacto não parece apresentar **sinergias** com outros impactos previstos na mesma fase" (AMB, 2007, p. 9). Não foi avaliada a sinergia entre as fases, mas sim entre os impactos ocorridos na mesma fase.

Tabela 4 | Exemplos dos impactos ambientais listados e a descrição qualitativa dos impactos ambientais considerados com atributo de sinergia no EIA do 3P Porto Pontal

	Impacto (Natureza): Descrição
1	Piora da qualidade de vida por insuficiência de infraestrutura básica e serviços públicos (N): "Possui sinergia com a inibição da afluência de turistas, na medida em que a piora dos serviços será um elemento a mais que os poderá desestimular de optar por Pontal do Paraná para seu descanso, o que, por sua vez, pode reverter em piorar mais a situação, por perda dos recursos aportados por estes" (p. 162)
2	Incremento de problemas de segurança pública (N): "Mas haveria sinergia com a inibição da escolha dos turistas pelo município, no sentido de, em parte, motivá-la, e de que, por sua vez, esta reverteria em propiciar pobreza e desagregação social, por implicar diminuição de fontes de renda." (p. 163)
3	Incremento de prostituição (N): "A sinergia com a possível inibição da afluência de turistas poderá ser maior pelo incremento do problema" (p. 163)

Legenda: (N) Impacto Negativo.

Fonte: Elaborada pelas autoras a partir do EIA do GPD 3P Porto Pontal.

O EIA da Subsea7 considerou a sinergia como atributo. Por exemplo: Impacto: Dispersão da poluição sonora; Atributo: Sinergia com outros impactos/riscos; Qualificação: Aumento do efeito de borda nas áreas adjacentes à ADA; Distúrbios à fauna terrestre em geral pela emissão de ruídos; Modificação do uso de *habitat* por espécies de mamíferos de médio e grande porte; Afugentamento e distúrbios à fauna aquática.

Os demais EIAs dos GPDs (Odebrecht, Melport e Faixa de Infraestrutura) não atenderam ao critério.

CRITÉRIO F.

Os EIAs dos GPDs 3P Porto Pontal, Odebrecht, Melport e Faixa de Infraestrutura e Subsea7 não atenderam ao critério. O EIA da Subsea7 utilizou pesos e atributos para avaliação da importância do impacto, o que não reflete necessariamente na previsão da magnitude do impacto. O peso atribuído à sinergia se deu por: 1 – não sinérgico; 3 – sinérgico. A metodologia para definir a valoração e a importância do impacto ambiental considerou os seguintes atributos: "VALORAÇÃO = (NATUREZA) X (1,0 X IMPORTÂNCIA) + (0,9 X PROBABILIDADE DE OCORRÊNCIA) + (0,8 X ABRANGÊNCIA) + (0,7 X SINERGIA)".

CRITÉRIO G.

O EIA do empreendimento Subsea7 considerou o atributo de sinergia e descreveu a metodologia para identificar a sinergia do impacto. De acordo com o EIA, considerou-se presença e ausência a partir da relação direta com outro impacto e o consequente aumento dele, independente de ser atribuído como positivo ou negativo (ver transcrição já utilizada no critério D). Ademais, "quando o impacto for **sinérgico**, devem ser citados os impactos que podem ter seus efeitos agravados" (AAT, 2009, p. 1101).

O 3P Porto Pontal, apesar de considerar o atributo de sinergia, não apresentou metodologia coesa em relação à avaliação, porém, menciona que "para determinar o caráter sinérgico ou não, e a relevância, se pensou **cada impacto em relação aos outros presentes na mesma fase**" e assim o fizeram, conforme Tabela 4 do critério E.

Os EIAs referentes aos GPDs Odebrecht, Melport e Faixa de Infraestrutura não atenderam ao critério até porque não identificaram os ICs no processo de avaliação.

CRITÉRIO H.

Nenhum dos estudos atendeu a este critério. O GPD Melport menciona a existência de outros projetos de empreendimentos na área, mas não há menções de incertezas sobre ICs.

Os dois TRs que solicitaram a consideração dos ICs não apontaram uma metodologia de avaliação desses impactos, o que evidencia o contexto apontado pelos trabalhos de Barros e Pereira (2019) e de Montaño *et al*. (2014), quando elencam a indevida consideração aos ICs no processo de licenciamento ambiental e os resultados insatisfatórios nas AIAs devido à ausência de instrução técnica adequada. Além disso, notou-se que, por se tratar do mesmo órgão ambiental responsável, os documentos são padronizados mesmo que os empreendimentos contemplem atividades expressivamente diferentes. O problema se aprofunda quando se considera que a Faixa de Infraestrutura agrega sete atividades diferenciadas no mesmo projeto e processo de licenciamento. Nessa tratativa, Neri *et al*. (2016, p. 296), ao analisarem o estado-pressão-resposta para AIC de empreendimentos no estado de Minas Gerais, apontam que a generalização dos TRs para preparação dos EIAs é uma das causas de inconsistência ou indisponibilidade de dados.

Do ponto de vista técnico, os resultados demonstraram que os TRs são orientados pela Resolução 1/86 do Conama, na qual recomenda-se que se considere as "propriedades" cumulativas e sinérgicas do impacto. Os TRs dos empreendimentos que sugerem considerar os ICs na avaliação seguem essa mesma orientação. Nota-se que esse encadeamento de orientações entre Conama e o órgão ambiental responsável pela elaboração do TR reflete na elaboração dos estudos. Sánchez (2020) pontua esse equívoco comum em relação ao que se espera de uma avaliação dos impactos cumulativos. Para o autor, "avaliar impactos cumulativos não é o mesmo que indicar, em um EIA, se determinado impacto tem 'propriedades cumulativas ou sinérgicas', como é prática comum no Brasil" e pode ser reafirmado nos casos analisados. Essa inconsistência e indefinição, desde o percurso inicial do licenciamento ambiental demonstrado pelos TRs, permeiam as precariedades dos estudos de impacto referentes e comprometem uma avaliação séria e rigorosa dos ICs. Nesse sentido, Siqueira-Gay *et al.* (2019) destacam que "os Estudos de Impacto Ambiental precisam de diretrizes detalhadas para aprimorar os estudos relacionados a interações potenciais entre os impactos", chamando atenção para a preparação dos próprios TRs. O caso em tela demonstra os problemas de distanciamento entre os trabalhos teórico-conceituais da ciência e a prática e aplicação profissional da AIA, destacados por Morgan (2012). Então, ressalta-se que, mesmo que o sinergismo e a atenuação estejam relacionados com os ICs, tais termos são utilizados como atributo vinculado à propriedade do impacto.

No caso do empreendimento TCPP, além de não ter recomendações do órgão ambiental para consideração dos impactos cumulativos, tem sido objeto de batalhas judiciais e envolveu a tentativa de pré-candidatura do empresário nas eleições municipais de Pontal do Paraná em 2020, onde encabeçou a chapa com o emblema "A Pontal que Nós Queremos", na qual os objetos centrais de campanha foram a construção do novo porto e da estrada (Nova Faixa de Infraestrutura). Mais tarde, o empresário desistiu da candidatura que, segundo notícias, foi motivada pela operação da Polícia Federal, em que "ele foi um dos alvos da ação que apura irregularidades para a concessão de licença ambiental para a Porto Pontal Paraná Importação e Exportação SA" (REVISTA OESTE, 2020). De acordo com notícia veiculada no G1, "o empresário é investigado pela Polícia Federal (PF), suspeito de pagar propina de mais de R$ 1 milhão para obter uma licença ambiental para a instalação de um novo porto em Pontal do Paraná" (G1, 2020).

Não obstante, o caso da Odebrecht destaca a necessidade de o estado do Paraná estabelecer uma base de dados que facilite o acesso às informações ambientais públicas e que rompam as barreiras para o desenvolvimento científico e, com isso, melhores práticas políticas e profissionais. Autores como Foley *et al*. (2017), Murray *et al.* (2014) e Olagunju e Gunn (2015), ao tratar de AICs, identificam a indisponibilidade de dados ou dificuldade de acesso como uma das barreiras para o desenvolvimento desta ciência. Foley *et al.* (2017) avançam e identificam no problema a oportunidade de investimento para o desenvolvimento de base de dados, ferramentas e modelos regionais que alinhem a ciência, a política e a prática.

Em relação à presença e ausência dos termos nos EIAs, o empreendimento Odebrecht não atendeu a este critério. Nos outros quatro estudos, foram identificados com maior frequência os usos dos termos "sinergia" ou "sinérgico" como um atributo da matriz de impacto, definindo apenas presença e ausência. Como destacam Barros e Pereira (2019) e Montaño *et al.* (2014), os ICs são tratados de maneira inapropriada, apresentando uma séria confusão em relação aos termos utilizados. Barros e Pereira (2019) identificaram que "a cumulatividade foi tratada erroneamente como uma propriedade do sinergismo". De forma semelhante, notou-se que nos EIAs dos empreendimentos, novamente, indicou-se a sinergia como um atributo relacionado à propriedade do impacto, prática essa apontada por Sánchez (2020) e mencionada acima. Quatro empreendimentos não apresentaram definição dos termos e dois deles, a Faixa de Infraestrutura e Melport, receberam determinação nos TRs de considerar os ICs em seus estudos técnicos de avaliação do impacto.

Os ICs nas fases de planejamento, implementação, operação e desativação não foram considerados em três EIAs (Melport, Odebrecht e Faixa de Infraestrutura). O uso do termo "sinergia" como um atributo dos impactos foi identificado nos EIAs dos empreendimentos TCPP e Subsea7 dentro das respectivas fases, portanto, considerou-se como parcial a abordagem dos ICs, por fase. A ausência de definição do termo e de metodologia fomenta uma confusão ao utilizar a sinergia como um atributo. Fator que pode ser confirmado no estudo de Barros e Pereira (2019), possivelmente considerado uma negligência costumeira que precariza os estudos ambientais.

No caso específico da Odebrecht, notou-se que a avaliação de impactos foi voltada para as fases de planejamento e instalação e não abordou a fase de operação, o que pode ser justificado pelo empreendedor em função do uso anterior das instalações para outras atividades industriais. Esse apontamento levanta preocupação em relação à insuficiência da análise dos impactos cumulativos e a determinação de uma linha de base histórica e espacial (OLAGUNJU; GUNN, 2015; SPALING, 1994) sobre os impactos que já foram deixados no ambiente devido sua operação na década de 1980, seu processo de desativação e o estado atual, anos após os ecossistemas estarem em recuperação. Esse último é um importante diferencial em uma AIC propriamente dita, em que suas etapas partem primordialmente da seleção de Componentes Ambientais e Sociais (CASS) importantes e sua situação, diferente da AIA que tem seu foco principal na atividade/impacto (SÁNCHEZ, 2020).

A abordagem qualitativa e quantitativa de ICs demonstrou-se insuficiente. Não se aportou uma análise interprojetos, e apesar de os resultados apontarem para uma abordagem do atributo de sinergia dos impactos nos intraprojetos dos empreendimentos Subsea7 e TCPP, o estudo apresentou uma análise descritiva, sem atentar para escalas espaciais e temporais, além de apresentar uma lacuna nas interações entre as fases, que são importantes da mudança ambiental cumulativa. O empreendimento Subsea7 foi a única exceção em quantificar o atributo de sinergia para definição de magnitude do impacto e descrever a metodologia para tanto. Apesar disso, cabe ressaltar que a menção ao atributo de sinergia não condiz com uma abordagem de ICs que corroborem o exposto por Spaling (1994) e, assim, o estudo é insuficiente na identificação e avaliação de impactos cumulativos. A metodologia para identificar e avaliar ICs não foi identificada nos demais EIAs e as incertezas quanto aos ICs não foram apresentadas. Apesar de esta pesquisa estar limitada a um conjunto de cinco empreendimentos projetados colocalizados em um único município do litoral do Paraná, ela faz uma primeira aproximação comprovada e reforçada de que o tratamento de ICs é um ponto inexistente ou insuficientemente trabalhado nos TRs e EIAs que estão circunscritos ao processo de exame da AIA, como argumentado por Montaño *et al.* (2014) e Neri *et al.* (2016).

Fase *et al.* (2011), ao questionarem a tecnocracia que envolve o sistema de AIA e percorre o processo de licenciamento ambiental, sugerem que os métodos dos EIAs são "apropriados pelos interesses econômicos envolvidos no projeto e na própria elaboração repetida de estudos de impacto formalmente padronizados e socialmente vazios". Tem-se por base a descrição qualitativa de alguns impactos considerados com atributo de sinergia no EIA do 3P Porto Pontal, a exemplo do 1. Incremento de Prostituição; 2. Piora da qualidade de vida por insuficiência de infraestrutura básica e serviços públicos; e 3. Incremento de problemas de segurança pública, interagindo com 4. Inibição de turistas. Então, como o Estado, agentes corporativos e a população local enfrentarão o aprofundamento de problemáticas a partir da instalação de um novo complexo industrial portuário no município? A pergunta segue não respondida, visto que a avaliação de impactos, da forma como é realizada, é insuficiente e ineficiente, pois não analisa a evidente interação entre, por exemplo, esses quatro impactos. Mais do que isso, não considera a condição histórica e futura dos CASS afetados e das interações dos impactos interprojetos (SÁNCHEZ, 2020), especialmente quando se assume que a ocupação socioespacial do Complexo Estuarino de Paranaguá já atende atividades de alto impacto ambiental dada a presença do Porto de Paranaguá e Antonina, além de outras atividades industriais (ABRAHÃO; CANEPARO, 2014).

Bronz (2013) apresenta a estratégia do discurso empresarial de que o "Estado não sou eu" quando consequências socioambientais negativas são desencadeadas e aprofundadas pela instalação de grandes projetos. Nesse caso, novas perguntas podem ser atribuídas à resiliência institucional do Estado para o enfrentamento dos problemas provenientes desses vetores econômicos. Guzmão (2010, p. 35) destacou que "é forçoso perguntarmos se esses agentes – que se situam na linha de contato imediato entre as novas pressões emergentes e as velhas deficiências imobilizantes – serão capazes de agir estrategicamente".

Por fim, constatou-se que o processo de exame da AIA dos projetos individuais mostrou não dar conta da análise dos ICs. Esse resultado não se distancia do que a ciência tem apontado, pois, conforme sugerem Neri *et al.* (2016), apesar de confirmada a necessidade de aplicação da AIC para cenários como de Pontal do Paraná, "as abordagens e métodos comumente aplicados à avaliação de impacto ambiental de um projeto individual podem não ser adequados". As dificuldades e limitações são ainda maiores quando se consideram projetos simultâneos de diferentes proponentes, tipologias e concentrados espacialmente. Eis que o presente artigo evidencia um cenário complexo e incerto, no qual não se tem ciência sobre o que de fato a apropriação do espaço pelo conjunto de empreendimentos desencadeará a curto, médio e longo prazo, especialmente para as comunidades costeiras mais vulnerabilizadas e ambientes naturais e culturais importantes.

5 CONSIDERAÇÕES FINAIS

O objetivo de analisar se e como os TRs e EIAs dos grandes projetos do Complexo Industrial Portuário de Pontal do Paraná avaliam os impactos cumulativos foi realizado. Apesar disso, se reconhece que essa foi uma primeira aproximação que certamente se limitou às tratativas ligadas ao projetos e não às outras possíveis fontes geradoras de impactos, a exemplo de eventos naturais. Também se limitou ao enfoque local, abstendo-se da escala regional. A partir disso, o objetivo propiciou considerar os seguintes pontos:

1. A insuficiência de abordagem dos ICs faz parte da racionalidade em que a AIA foi concebida e é destacada amplamente pela literatura. Soma-se a isso inúmeras denúncias evidenciando que os processos decisórios envolvendo os grandes projetos são previamente tomados e as avaliações são, em sua maioria, limitadas à reprodução de aceitação pública do empreendimento. Dessa forma, destaca-se a disputa judicial e a investigação do caso de envolvimento na compra de licença ambiental alinhada ao empreendimento Porto Pontal, que torna mais grave o cenário.

2. Consequentemente, apesar das licenças concedidas, os GPDs vinculados ao CIP não têm análise suficiente dos ICs. Isso ocorre desde o processo inicial do licenciamento ambiental com a elaboração engessada dos TRs, a qual ainda é distante das discussões científicas no campo da avaliação de impacto, mostrando-se ineficaz para identificação e avaliação dos ICs. Sugere-se que um processo assertivo de avaliação de impacto, com foco nos impactos cumulativos e suas metodologias, deve levar em conta o conjunto dos empreendimentos e o planejamento territorial que antecedem avaliações meramente individuais com empreendimentos já pré-aprovados. Para isso, podem ser acionadas diversas tipologias de AI que são discutidas e implementadas mundialmente, a exemplo da AIC, da AAE e da AAI, essas duas últimas já sendo utilizadas em contextos de instalação de PCHs na região amazônica.

3. A concessão individual das licenças ambientais e a insuficiência do processo de AIA em abordar os ICs levantam sérias preocupações em relação a um possível cenário de incertezas do ponto de vista socioambiental proporcionado pela instalação do conjunto dos empreendimentos em Pontal do Paraná. Esse ônus pode ser considerado quando se evidencia o caso de expropriação territorial de uma comunidade tradicional de pescadores (*i.e.* Ponta do Poço), além do risco de dois novos casos (TI Sambaqui e Comunidade de pescadores do Maciel, ver Figura 1). Além desse tensionamento devido à sobreposição de territórios em disputa, alerta-se para o aumento do desmatamento com a perda de áreas de Mata Atlântica consideradas de extrema relevância para a conservação da biodiversidade (MMA, 2018) e mantimento da cultura e do saber-fazer de diferentes grupos étnicos que habitam a região e confluem com este importante bioma.

4. Como limitações, se reconhece que a dimensão do poder foi pouco abordada neste artigo. Diante dessa lacuna, considera-se importante refletir sobre como as questões intrínsecas ao sistema moderno colonial e capitalista ainda seriam peças-chaves no exercício da democracia e nas influências das relações de poder nos processos decisórios, ou, mesmo com a melhor avaliação dos impactos cumulativos no processo administrativo do licenciamento ambiental, a influência das relações de poder ainda seria relevante na decisão final dos processos decisórios?

NOTAS

1 | O licenciamento ambiental está inserido na Política Nacional de Meio Ambiente, Lei n° 6.938 de 31 de agosto de 1981. Duas Resoluções do Conselho Nacional de Meio Ambiente (Conama) são importantes para o início da aplicabilidade da AIA no Brasil: a Resolução n° 1/1986, que trata de critérios, definições, responsabilidades; diretrizes gerais para uso e implementação

da AIA e inclusive institui o Estudo de Impacto Ambiental e Relatório de Impacto Ambiental (EIA/Rima), e a Resolução n° 237/1997 que apresenta a revisão dos procedimentos e critérios de licenciamento ambiental.

2 | Atualmente, apenas a empresa Techint mantém sua empresa instalada, porém, encontra-se desativada.

3 | O Termo de Referência (TR) do GPD Odebrecht não pode ser obtido mesmo após requerimento formal ao Instituto Água e Terra (IAT) e solicitação do Grupo de Apoio Especializado em Meio Ambiente (Gaema) do Ministério Público do Estado do Paraná.

4 | Fase da licença até a data de consulta em 2020.

5 | O EIA de 2010 trata-se de um pedido de complementação acerca do meio físico e biótico. O próprio EIA explica quais foram as complementações solicitadas pelo órgão ambiental, por esse motivo, optou-se por não analisar o parecer técnico com o pedido de complementação. Ademais, no EIA complementar, não foram encontradas menções de complementações a respeito dos impactos cumulativos, foco desta análise.

6 | O Termo de Referência (TR) do GPD Odebrecht não foi analisado por não ter sido disponibilizado pelo órgão ambiental estadual.

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Composition of the social urban water shortage vulnerability index (SUWSVI) applied to São José dos Campos, SP, Brazil

Composição do índice de vulnerabilidade social urbana de falta de água (SUWSVI) aplicado a São José dos Campos, SP, Brasil

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ABSTRACT

Mining dams within urban areas are a technological risk because, in the event of an accident, they affect water security. For example, a sand mining dam accident caused an interruption in the water supply in the downstream city of São José dos Campos. Thus, the social vulnerability of the population that suffered from a failure in the drinking water supply was evaluated. A water shortage indicator, the Social Urban Water Shortage Vulnerability Index – SUWSVI, was composed. Variables that best reflect the socioeconomic condition were used: Average Income of Head of Household, Female Head of Household, and Children and Elderly Dependent Ratio. The sensitivity analysis considered the city by geographic regions and zoning classes, considering infrastructure supply and lot size. The results showed that although there are full water supply and sewerage infrastructure (99.6%), the access to water was unequal (39% of the population in the medium SUWSVI range).

Keywords: Social vulnerability. Water shortage indicator. Technological risks. Water security.

RESUMO

As barragens de mineração em áreas urbanas são riscos tecnológicos porque, em caso de acidente, afetam a segurança da água. Um acidente com uma barragem de mineração de areia causou interrupção no abastecimento de água na cidade de São José dos Campos, a jusante. Com isso, foi avaliada a vulnerabilidade social da população que sofreu com a falha no abastecimento de água potável. Um indicador de escassez de água, o Índice de Vulnerabilidade Social Urbana de Falta de Água – SUWSVI, foi composto. Foram utilizadas as variáveis que melhor refletissem a condição socioeconômica: Renda Média do Chefe de Família, Mulher Chefe de Família e Relação de Dependência de Crianças e Idosos. A análise de sensibilidade considerou a cidade por regiões geográficas e classes de zoneamento, que levam em conta a oferta de infraestrutura e o tamanho do lote. Os resultados mostraram que, embora com infraestrutura completa de abastecimento de água e esgoto (99,6%), o acesso à água foi desigual (39% da população na faixa média SUWSVI).

Palavras-chave: Vulnerabilidade social. Indicador de falta de água. Riscos tecnológicos. Segurança hídrica.

1 INTRODUCTION

As depicted in United Nations' Sustainable Development Goal SDG no. 6 (UN, 2015), access to water and sanitation for humankind is a challenge for all and a duty for governments. Water security needs to be guaranteed (GREY; SADOFF, 2007), but the different realities of countries require commitment and different solutions. The high population density added to the demand for water resources, often polluted, turns water supply in cities a challenge, generating conflicts of use due to its quality and quantity (PEREIRA *et al.*, 2020). Water security is water availability and the right to use drinking water for present and future generations. It includes regional and global water availability, environmental issues, access complexity, and water scarcity (HOPE; HOUSE, 2013; VÖRÖSMARTY *et al.*, 2010). Dams are an example of water resources management infrastructure that can increase water security in a region (VÖRÖSMARTY *et al.*, 2010). However, the existence of water-related infrastructure is no guarantee that access to water is equal (LOPES, 2020). Drinking water supply and water security are compromised if water reaches consumption limits, exceeds its carrying capacity, or if there is proven contamination in the distribution system (RAVAR *et al.*, 2020). In addition, solutions for water availability, such as the construction of surface reservoirs, add risks and increase vulnerability, as it causes suppression of vegetation, a decrease of biodiversity, plus the disastrous consequences in case of rupture. (CIONEK *et al.*, 2019; RENN; BENIGHAUS, 2013).

Social vulnerability is a condition that makes people or groups of people more susceptible to harm than others (RECKIEN, 2018). Water-related social vulnerability can be monitored through indices of equality in access to water and sanitation (MUKHERJEE *et al.*, 2020). Studies of indicators to assess non-discrimination and equity in the context of the human right to water and sanitation guide public

policy (AMJAD *et al.*, 2014) and understand events that disrupt the normal functioning of communities, putting them at risk (LUNDIN; MORRISON, 2002).

To construct a vulnerability index, it is necessary to use latent variables, intrinsic to some place, not directly observable, and that can only be indirectly measured by statistical procedures. For example, an area's demographic data allow quantitatively defining social vulnerability (SPIELMAN *et al.*, 2020), just as the feature due to abrupt interruption in the water supply is not directly observable. Also, sensitivity analysis (OECD, 2008; TATE, 2012) is needed to choose the variables that had the greatest influence on the expression of the results. These indices are characterized as composite indicators (BECCARI, 2016; MOREIRA *et al.*, 2021; OECD, 2008), of synthetic nature (SPIELMAN *et al.*, 2020) and multidimensional. The latter condition brings complexity to the construction of the index but allows the comparison of various sources and scales and gives alternatives to consider missing data and approximate non-existent information from related data (ANAZAWA *et al.*, 2013; RUFAT *et al.*, 2019). Therefore, as the various existing social vulnerability indices have complex validation because social vulnerability is multidimensional and not directly observable (FEKETE, 2012; RUFAT *et al.*, 2019), the choice of parameters needs to consider both the index configuration and the disaster measure (SPIELMAN *et al.*, 2020; TATE, 2012).

According to Rufat *et al.* (2019), in selecting the variables that lead to the understanding of social vulnerability, it is necessary to analyze which urban population was most affected by the difficulty of access to water and sanitation, relating it to the abrupt interruption of water caused by the dam burst accident. To do so, the variables surveyed need to cover several dimensions: biophysical, socioeconomic, gender-based, and water supply infrastructure (FATEMI *et al.*, 2016). The indices must reflect multidimensionality, interactivity, and causal processes (RUFAT *et al.*, 2019). A socio-hydrological analysis should include socioeconomic water values and aspects relevant to human well-being to assess the sustainability of water resources (SUN *et al.*, 2017).

Risks due to dams in urban areas can compromise water security and need to be taken into account when assessing social vulnerability. Risks cover various agents and causes (FEKETE, 2012; VEIRET, 2007; WOOD *et al*., 2021).

Measuring the social vulnerability of communities near infrastructure that pose water-related risks when an accident occurs is essential. Regardless of size, these infrastructures are embedded in cities, bringing a perennial risk. Brazil has a history of mining dam disasters that have caused incalculable socioeconomic and environmental impacts and can take decades to recover (50 million m^3 of iron ore mining tailings released into the Doce River from the collapse of the Fundão tailings dam in Mariana and 13 million m^3 of tailings into the Paraopeba River from the Córrego do Feijão tailings dam in Brumadinho, both Minas Gerais State) (CIONEK *et al.*, 2019; VORMITTAG *et al.*, 2018). In the study region (city of São José dos Campos, State of São Paulo, Brazil), the water-related risk is due to the sedimentation dams of ancient sand mines. Over 83 sand mining companies have settled in more than 250 km^2 along the shores of the Paraíba do Sul River, where the city's water catchment system is located. When the mines are active, the dams are constantly filled with tailings and the risk increases. On the other hand, when inactive or finished, they function as reservoirs and ecosystem services for water supply (FERRER *et al.*, 2021).

From the above, the objective of this work was to consider different indices of social vulnerability (WOOD *et al.*, 2021), to develop the Urban Water Shortage Social Vulnerability Index (SUWSVI), and map the changes in the household dynamics of the population coexisting with dams that represent water-related risks. The intention is to show local public managers the need for water supply planning by city region and neighbourhood to contemplate the most socially vulnerable groups.

2 MATERIALS AND METHODS

2.1 AREA OF STUDY

The city of São José dos Campos is located in the Paraíba do Sul River Basin in the southeast region of Brazil (Figure 1). The southeast is the country's most densely populated and developed region and comprises its three largest metropolitan regions (São Paulo, Rio de Janeiro and Belo Horizonte).

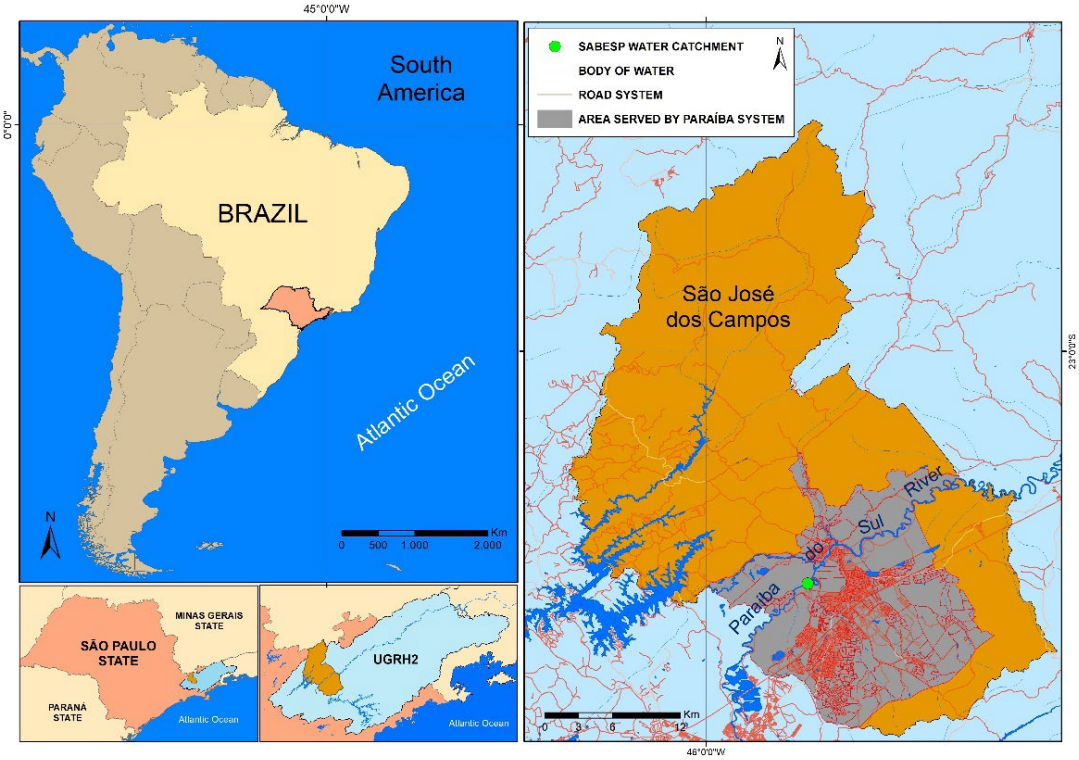

Figure 1 | Location of the study area. Urban area of São José dos Campos and public water supply through the Paraíba Subsystem. Water Resources Management Unit – UGRHI 02

Source: Prepared by the authors, based on Municipal Government of São José dos Campos (2017a), Department of Water and Electricity (DAEE, 2017), and Secretariat of Infrastructure and Environment of São Paulo State Government. Environmental Planning Coordination (2017).

The lowlands of the Paraíba do Sul River Basin, where São José dos Campos is located, have been exploited for more than 70 years for sand mining, leaving dozens of sand pits installed. The city has an estimated population of 729,737 (INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA, n.d.). These pits have impacted eco-hydrological processes due to hydraulic works, urbanization, and population growth. These infrastructures occur in more than 250 km² of river polders, very close to the water catchment system (FERRER *et al.*, 2021). The sand pits scenario in the river floodplain represents a perennial risk. The municipality of São José dos Campos, SP, had its water catchment system hit by the collapse of an upstream sand pit dam in 2016. Because this water catchment system serves the urban population of this municipality, the water shortage impacted most of the inhabitants. As related in local news and media, the impact was unequally perceived by inhabitants, which suggests different capacities for dealing with disaster in the city.

The studied population is located in an urban area with a full water supply and sewage infrastructure (MUNICIPAL GOVERNMENT OF SÃO JOSÉ DOS CAMPOS, 2017a). Of the 28 municipalities that collect water from the Paraíba do Sul River Basin, São José dos Campos has the largest served population (99,6% of de urban population). The water supply system is designed for approximately 750,000

inhabitants and divided into three subsystems: Paraíba (or Sede), the main tributary, Eugênio de Mello and São Francisco Xavier. The Paraíba Subsystem, the object of this study (Figure 1), has a yield capacity of 2,626 l/s, of which 1900 l/s originate from the Paraíba do Sul River, 12 l/s from the Couves River and the remaining 714 l/s from 48 deep tubular wells. It has approximately 1,699 km of pipelines and distribution networks and serves 172,573 active drinking water connections (MUNICIPAL GOVERNMENT OF SÃO JOSÉ DOS CAMPOS, 2017a). During the last decades, the increase in urban population density required an increase in individual water connections per household (HOPE; ROUSE, 2013).

In 1949, sand mining was installed in the Paraíba do Sul River to supply the local construction sector and the Metropolitan Region of São Paulo (SECRETARIAT OF INFRASTRUCTURE AND ENVIRONMENT OF SÃO PAULO STATE GOVERNMENT, 2017). Although subsidies for environmental planning are consolidated around the Vale do Paraíba river basin (SECRETARIAT OF INFRASTRUCTURE AND ENVIRONMENT OF SÃO PAULO STATE GOVERNMENT, 2017), impacts such as agricultural area expansion, deforestation, changes in river channel morphology, and mining in protected areas (SANCHÉZ; SANTO, 2002) have become permanent elements of the territory and affected ecosystem services supply, especially water provisioning (FERRER *et al.*, 2021).

Sand mining in São José dos Campos was eradicated in 1991; however, in 2016, a mining dam in an upstream town broke up. This was due to the improper discharge of effluent by a neighbouring mining company, which exceeded the retention capacity of the dam (long out of operation) and affected the city's water catchment system. The accident caused the interruption of piped water supply for 75% of the population for more than 30 hours (G1, 2016) because of increased turbidity, iron and aluminium values above safe threshold (GEOGRAPHIC AND GEOENVIRONMENTAL INFORMATION SYSTEM OF THE PARAÍBA DO SUL RIVER BASIN, n.d.). As a result, 94% of the urban area population was affected (approximately 695,992 inhabitants in 2016), with 97.65% of this total served by the Paraíba Subsystem (MUNICIPAL GOVERNMENT OF SÃO JOSÉ DOS CAMPOS, 2017a).

Differences in urbanization processes in the inner city can help to understand the unequal distribution of social vulnerability. Costa and Mello (2010) described the urbanization process of different regions of São José dos Campos describing different subdivisions. The urban region was classified into five classes according to the average land lot size and the existence of essential infrastructures such as running water supply, electricity supply and paved streets:

- Classes were named A, B, C, D, and small farms, where Class A is the subdivision with the largest land lot size and the best infrastructure availability, and class D has the smallest land lot size and poor infrastructure;

- Class A includes properties in high-standard closed condominiums, both vertical and horizontal, that offer strong security and leisure amenities. This class predominates in the West and Central regions of the city;

- Class B includes intermediate - to high-standard vertical gated communities and predominates in the West and Central regions;

- Class C and D are located far from urban centres, usually in high-slope areas for social housing programs. These areas are characteristic of socio-spatial and economic segregation. This class predominates in the South, Southeast, East, and North regions, where urban density was low at implementation, with a predominance of vertical gated communities and low-income housing;

- Farms occur mainly in the West, North and Southeast regions. They are adequately served in infrastructure, security, and leisure needs.

2.2 GEOREFERENCED DATABASES

The cartographic databases of the municipality used for this work were obtained from the 2010 Brazilian Institute of Geography and Statistics Census data (IBGE, 2017). The location of public water supply connections was obtained from the Department of Water and Electricity (DAEE, 2017). The socioeconomic indicators were prepared from information in 871 census sectors in São José dos Campos provided by the 2010 Census (IBGE, 2017). We also supplementarily analyzed over 1,300 citizen comments made on the *Facebook* profile of the Municipality of São José dos Campos (PREFEITURA DE SÃO JOSÉ DOS CAMPOS, 2016). The data were considered to reinforce how the decisions made in composing the isolated SUWSVI variables affected the final results and correlated to the local sensitivity analysis (TATE, 2012). This social media is often used creditably by public authorities for quick communication. Besides being a popular and easily accessible application for citizens, the data are stored with a temporal record. For example, social media can serve to debate the water crisis or even to stimulate social awareness and mobilize social organizations against public management (FISCHER *et al.*, 2018). The emotional content of the manifestations was disregarded, seeking only the count and geolocation of the comment. Risk perception and facing are complex aspects to be reflected in social vulnerability indicators (FEKETE, 2012).

Evaluating pre-existing social, cultural, economic, and political conditions allows the assessment of the formation of value judgments about the severity and acceptability of water-related risks based on psychological, social, and cultural factors (FEKETE, 2012; RENN; BENIGHAUS, 2013; RUFAT *et al.*, 2015).

For the index's composition, we selected the census variables that best reflected the socioeconomic condition of the population and the subdivision into zoning classes in the region (COSTA; MELLO, 2010). The vulnerability was analyzed beyond the population's exposure and resilience to risk (ANAZAWA, 2012). This approach considers the dynamics of the territory and its social relations, treating the place of residence as a common resource, indivisible and highly relevant for the security and well-being of families. In other words, it is a social-ecological analysis in which territory is considered an enhancer of social inequalities. Examples are the occupations of protected natural slopes of the Atlantic Forest in the Serra do Mar and mangroves (ANAZAWA *et al*., 2013). Social vulnerability is assessed as a result of the interactions between the availability of infrastructure, attributes of poverty and health risk, and factors related to environmental risk (BROUWER *et al*., 2007; TELLMAN *et al*., 2020).

We categorized variables to describe economic and social dimensions based on the Census data and elaborated variables and formulas for developing the SUWSVI index, presented in Table 1. To describe the economic dimension of vulnerability, we defined the variable "Average Income of Head of Household" (VEC1), which allows us to understand the impact of water purchasing on family income when the public network does not provide it. The lower the household income, the more difficult it is to face interruptions in the supply of public services since the purchase of water and containers significantly impacts household budgets. On average, a 20-liter gallon of water was R$ 5.00 (or US$ 1.28 2016/February). This price does not include the container's value which is returnable. According to the United Nations, each person needs 3,300 litres of water per month (about 110 litres of water per day) to meet consumption and hygiene needs; in Brazil, consumption per capita can reach more than 200 litres/day (MUNICIPAL GOVERNMENT OF SÃO JOSÉ DOS CAMPOS, 2017a). This translates to R$ 50.00/day/person, which is an expensive cost for a low-income family when it is considered that the national minimum wage was R$ 880.00 (US$ 225.82) per month at the time of the incident (BRAZIL, n.d.). To represent the importance of household income for vulnerability to shortages, we used the ratio between the census variable "Average Monthly Income Value of Persons Responsible for Permanent Private Households (with and without income)" (CENSUS1) and the census variable "Persons Responsible for Permanent Private Households" (CENSUS2), both

obtained from Census data. The value of three times the national minimum wage in effect in 2010, R$ 1,530.00 (US$ 392.62) (BRAZIL, n.d.), was used as a reference to classify households in the low- and very-low-income brackets.

For the social domain, we define two variables. The first, called "Female Head of Household" (VSOC1), was estimated as the rate between the census variables "Woman Head of Family" (CENSUS3) and "Head of household, total and men" (CENSUS4). VSOC1 allows us to understand gender inequality in society and the labour market when an incident impacts the paid working day and burdens the woman's daily domestic life. The second variable, called "Children and Elderly Dependent Ratio " (VSOC2), was estimated as the proportion of the sum of the Census variables "Under 10 Years Old" (CENSUS5) and "Elderly People - Over 60 Years Old" (CENSUS6), with the "Total Number of Residents" (CENSUS7). VSOC2 allows us to understand the difficulty of the head of the family in obtaining water to supply the number of dependents (children and the elderly), and there is an interruption in the public water supply.

The selection of variables to calculate the SUWSVI attempted to understand the urban distribution of populations most affected by water scarcity in São José dos Campos. The variable "Female Head of Household" - VSOC1 was chosen considering women's onerous and unequal social role in society and the labour market. The premise of the obligation of domestic work and childcare, insufficient public policies to facilitate the management of conflicting demands between home care and employment, combined with the low male participation in the division of unpaid work, had an impact on employment opportunities for women and mothers with dependent children and reinforced gender inequalities in the labour market (ANAZAWA *et al*., 2013; SORJ *et al*., 2007; TELLMAN *et al*., 2020). The variable "Children and Elderly Dependent Ratio" - VSOC02, reinforces the importance of VSOC01 because women are overburdened when an accident occurs. They stop their paid activities to normalize the situation at home and care for dependents. The dependents are the ones who spend most of the time inside the house and have a direct impact on the family's ability to find water sources because, besides the need for greater volume and extra cost per person, they have the less physical strength and accessibility (in the elderly the mobility difficulty is implicit) to help in the transportation and loading (ANAZAWA *et al*., 2013; SORJ *et al*., 2007; WOOD *et al*., 2021). The justification for the variable "Average Income of Head of Household" - VEC01 is that it reflects the ability of the head of household to cover the household budget (ANAZAWA *et al*., 2013; SORJ *et al*., 2007; TELLMAN *et al*., 2020; VORMITTAG *et al*., 2018; WOOD *et al*., 2021).

Table 1 | Components used to calculate the Social Urban Water Shortage Vulnerability Indicator (SUWSVI)

Domain	*Variable*	*Indicator Estimate*
Economic	Average Income of Head of Household (VEC1)	CENSUS2 / CENSUS1
Social	Female Head of Household (VSOC1)	(CENSUS3 / CENSUS4).100
	Children and Elderly Dependent Ratio (VSOC2)	(CENSUS5 + CENSUS6) / CENSUS7

Source: Prepared by the authors (2018) based on 2010 Brazilian Institute of Geography and Statistics (IBGE, 2017) Demographic Census Universe data

We applied a linear transformation (Equations 1 and 2) to each defined variable (VEC1, VSOC1 and VSOC2), forcing a scale variation between 0 and 1 (ANAZAWA, 2012). This scaling allows the aggregation of the variables for estimating the Social Urban Water Shortage Vulnerability Index (SUWSVI). Linearly transformed variables were estimated so that values close to 1 represent larger vulnerability than values close to 0. Thus, as both social domain variables, VSOC1 and VSOC2, are directly related to vulnerability, the larger the variable, the greater the vulnerability, and linear scaling was applied directly (Equation 1). However, the economic variable, VEC1, is indirectly related to vulnerability, so the scale was inverted (Equation 2)

$$eV = \frac{V_{ob} - V_{mn}}{V_{mx} - V_{mn}} \quad \text{Equation (1)}$$

$$eV = 1 - \frac{V_{ob} - V_{mn}}{V_{mx} - V_{mn}} \quad \text{Equation (2)}$$

Where:

eV = vulnerability scale

V_{ob} = Value obtained for the sector

V_{mn} = Minimum value observed between sectors for the indicator

V_{mx} = Maximum observed value between sectors for the indicator

After normalization (TATE, 2012), the SUWSVI value was obtained by calculating the average of the variables "Average Income of Head of Household" (VEC1), "Female Head of Household" (VSOC1), and "Children and Elderly Dependent Ratio" (VSCO2), thus establishing equal weights for each. Then, the spatial distribution of SUWSVI was obtained considering the polygonal geographical limits of each census sector. Seeking a product that allows simple and objective communication to decision-makers and the general public, the vulnerability ranges were estimated based on the distribution of SUWSVI values as follows: Very High (> 80), High (80-60), Medium (60-40), Low (40-20) and Very Low (<20).

3 RESULTS AND DISCUSSION

The estimated number of people per SUWSVI range revealed that 39% of the total population is in the SUWSVI Medium range, 24% are in low, 5% very low, 24% high, and 8% very high. Pondering the total result (FEKETE, 2012; TATE, 2012), most of the urban population of São José dos Campos suffered from water shortage within a context of ample water supply infrastructure. Although the interruption lasted only 30 hours, the vulnerability to the danger posed by perennial dams in the landscape is significant. The environmental recovery of closed mines has been limited to the simple stabilization of the physical environment, and these dams are permanently subject to the deposition of waste, which can reach the waters and endanger the surrounding population (MECHI; SANCHES, 2010). Like Sherbinin *et al*. (2019), who consider that vulnerability analyses highlight the underlying factors that put people and infrastructure at risk, mining dams were considered an ongoing risk in the region for the SWISVI study.

Spatial analysis of SUWSVI highlights the city's unequal distribution of social vulnerability (Figure 2).

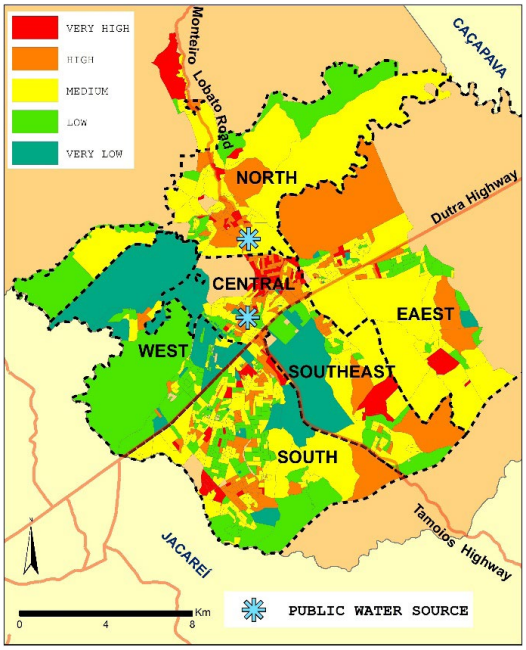

Figure 2 | Range Brackets of the SUWSVI – Social Urban Water Shortage Vulnerability Indicator, São José dos Campos, 2010

Source: Prepared by the authors (2018), based on 2010 Brazilian Institute of Geography and Statistics, Demographic Census Universe data (IBGE, 2017) and Municipal Government of São José dos Campos (2017a,b).

The distribution of the population by SUWSVI range in the administrative regions of the city (Figure 3) reveals that the South and Center regions have the largest number of people in the Very High SUWSVI range (> 14000), followed by the North region (> 7000). Approximately 80% of the population living in the South region are in the Low and Very Low SUWSVI range. The South region is the most populous. Input variables can be subjective and weighted, interfering with the result of vulnerability indicators (WOOD *et al*., 2021). To re-signify and validate the perception of social vulnerability by the distribution of census data, SWISVI was aggregated with the population density variables and occupation patterns by region. This is because social vulnerability is not a directly observable phenomenon, and since there is no device to measure it, its validation requires proxies (DE SHERBININ *et al*., 2019; TATE, 2012).

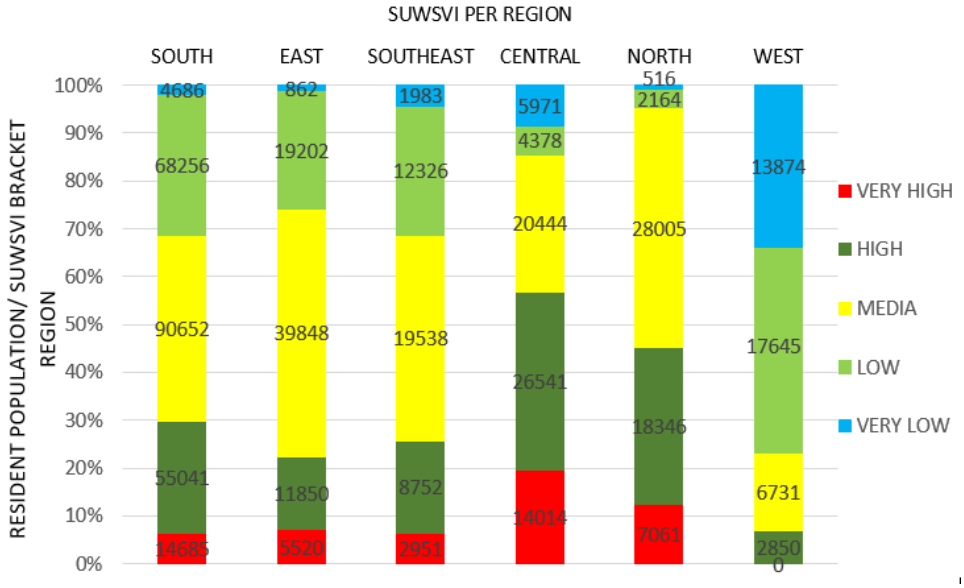

Figure 3 | Populational distribution by city region and SUWSVI

Source: Prepared by the authors (2018) based on Municipal Government of São José dos Campos (2017a).

SUWSVI shows significant differences between ranges and their regions of predominance. We sought to better understand this relation in the most affected census sectors by associating results with testimonies on the *Facebook* social network (PREFEITURA DE SÃO JOSÉ DOS CAMPOS, 2016). Quintslr (2018) also used media data to observe the social construction of the hydric crisis and demonstrate how the hegemonic discourse on the risk of shortages has contributed to keeping the issue of inequality out of decision-making spheres. It must be acknowledged that it was not possible to apply an appropriate multi-criteria analysis method (e.g. analytical hierarchy process AHP) (DE BRITO *et al*., 2018). However, this supplementary consultation was maintained to consider all intermediate manifestations around the accident and its intercurrences that would assist in interpreting the results.

The Central region has three isolated sectors with Very High SUWSVI (Figure 4). These sites are close to public parks that provide free access to potable groundwater sources. The deep wells of public parks helped with logistics in the Center region by supplying water from public sources (MUNICIPAL GOVERNMENT OF SÃO JOSÉ DOS CAMPOS, 2016).

At these places in the Central region, the "Female Heads of Household" (Figure 4a) and "Children and Elderly Dependent Ratio" (Figure 4c) are the most influent variables, meanwhile "Average Income of the Head of Household" (Figure 4b) has a low influence. These sectors comprise A- and B-class urbanization (COSTA; MELLO, 2010). Despite being relatively close geographically to the previous one, a second sector in the Central Region was more influenced by the "Average Income of the Head of Household" variable, which was the main driving influence (Figure 4b) for vulnerability. This is an Environmental Protected Area, named Banhado Permanent Preservation Area (MUNICIPAL GOVERNMENT OF SÃO JOSÉ DOS CAMPOS, 2017b), which has been occupied by a very low-income community living in non-regularized housing (MUNICIPAL GOVERNMENT OF SÃO JOSÉ DOS CAMPOS, 2017b).

Another Very High SUWSVI region appears in an agglomeration of sectors in the Central region (Figure 4), where B-type urbanization is identified (COSTA; MELLO, 2010). Units here are predominantly multifamily residences and commercial spaces, and the variable "Children and Elderly Dependent Ratio" (Figure 4c) is the dominant influence.

In comments on the social network *Facebook*, business establishment owners reported that they were without water all day after February 05, 2016 (the day of the dam collapse accident). They also said they had to close and suffered losses (PREFEITURA DE SÃO JOSÉ DOS CAMPOS, 2016). The development of new indices increasingly involves target populations with participatory approaches (DE BRITO *et al*., 2018).

In the South region (Figure 4), Very High SUWSVI values are found for a sector with the irregular occupation of private property by a very low-income community (BRAZILIAN INSTITUTE OF GEOGRAPHY AND STATISTICS, n.d.; MUNICIPAL GOVERNMENT OF SÃO JOSÉ DOS CAMPOS, 2017a). These values do not reflect conditions at the time of the study since census data was collected in 2010, and the area was unoccupied and returned to owners in January 2012, before the dam collapsed in 2016.

The area of Very High vulnerability located between the most important highways in the region, President Dutra and Tamoios routes (Figure 4), includes C-type urbanization and a mixed zoning area with the greatest diversity of uses in the municipality (MUNICIPAL GOVERNMENT OF SÃO JOSÉ DOS CAMPOS, 2017b). In this area, the vulnerability was chiefly influenced by the "Average Income of the Head of Household" (Figure 4b) and "Children and Elderly Dependent Ratio" (Figure 4c) variables. These are isolated sectors between fast-traffic roads and a planning zone which comprises empty plots and require a master plan for urban occupation in order to improve local mobility and territorial integration conditions. It also borders the Airport Zone, which makes access to the site difficult.

The South region has the highest number of comments on the *Facebook* social network about water shortages (PREFEITURA DE SÃO JOSÉ DOS CAMPOS, 2016). There, water supply for the local municipal

school was used to aid the region during the crisis ("VAZAMENTO DE REJEITO DE MINERAÇÃO NO RIO PARAÍBA É CONTIDO EM JACAREÍ, SP", 2016).

The North, East and Southeast regions (Figure 2) have isolated pockets in the Very High SUWSVI range. In the North region, Very High SUWSVI values are found in one sector at the extreme end of the Monteiro Lobato State Highway and in C- and D-class urbanization in areas bordering rural area farms. At these places, the Average Income of the Head of Household (Figure 4b) is the most influential variable for high SUWSVI values. In the East region, the four sectors with Very High SUWSVI values were geographically dispersed but all close to the Presidente Dutra Interstate Highway. The "Average Income of the Head of Household" variable was also the chief contributor to the high SUWSVI values. A network of deep wells installed almost 30 years ago ensured no local shortages occurred in a planned neighbourhood, with A-class urbanization, built in the 1970s (COSTA; MELLO, 2010; PREFEITURA DE SÃO JOSÉ DOS CAMPOS, 2016), as reported in comments on *Facebook*. In the Southeast region, Very High SUWSVI areas are found in three recently expanded sectors located on a back-roads with C- and D-class urbanization (COSTA; MELLO, 2010). In the West region, where urbanization is mostly comprised of A-class and farms (COSTA; MELLO, 2010), no sector shows Very High SUWSVI values.

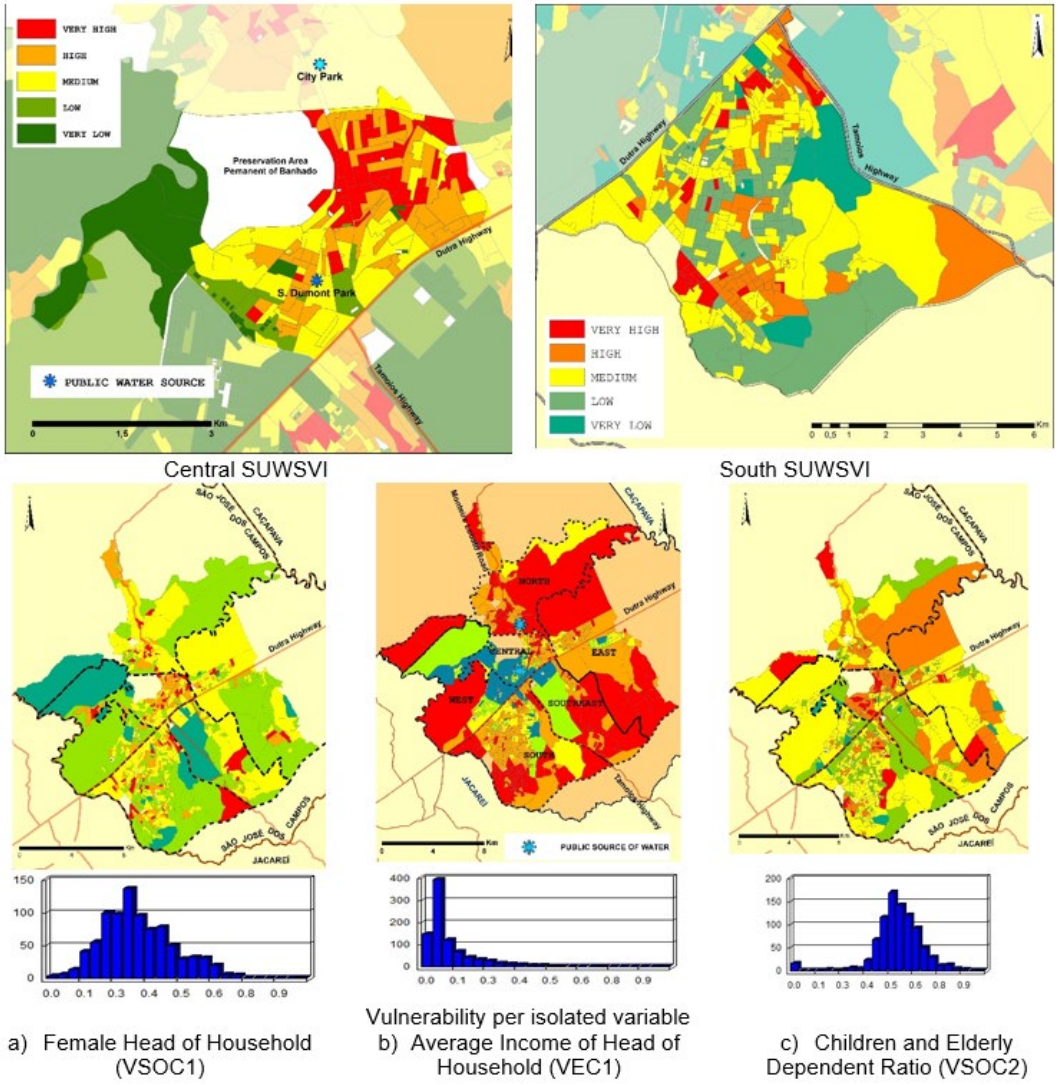

Figure 4 | Central and South urban regions and vulnerability per isolated variable

Source: Prepared by the authors (2018), based on 2010 Brazilian Institute of Geography and Statistics, Demographic Census Universe data (IBGE, 2017.) and Municipal Government of São José dos Campos (2017a,b).

Results show that "Average Income of the Head of Household" is the variable most likely to contribute to Very High SUWSVI values, followed by "Children and Elderly Dependent Ratio". The "Female Heads of Household" variable plays a secondary role. On the other hand, we do not overlook the importance of two other variables (Figure 4 a, c). Gender invisibility is evident because women solve the incompatibilities between the labour market and family responsibilities (SORJ, 2013). Moreover, the historical discrepancy in the sexual division of housework caused by difficulties in accessing water has resulted in public programs implementing cisterns prioritizing female-headed households, as they view them as better managers in water use (MEZA, 2017; NOGUEIRA, 2017).

4 CONCLUSIONS

The Social Urban Water Shortage Vulnerability Indicator (SUWSVI) was developed to analyze the social vulnerability of urban populations to occasional water shortage incidents. Our case study reveals that SUWSVI can capture the heterogenous vulnerability distribution in the city. The results show that 39% of the population has a medium vulnerability, mainly characterized by the lowest incomes and a larger number of dependents on this income. At the public management level, it helps the municipality to plan in which areas of the city it needs to act more quickly to reduce the impacts caused by water shortages. SUWSVI could be applied to the other adjacent municipalities with sand mining pits. Strategies to minimize vulnerability to water scarcity could be taken jointly among the municipalities, promoting public governance.

Besides this result, SUWSVI allows us to assess vulnerability distribution in the city and its relation to the population and the unequal urbanization process. It identified and mapped groups that faced challenges accessing water since it was not provided via public supply.

SUWSVI highlighted the city's social vulnerability to water shortages by plotting the combined values of social and economic variables. Because of its ability to identify economic, household, and mobility vulnerabilities of the populations, SUWSVI serves as a tool for planning and managing risks in accidents that interrupt the supply of drinking water for a long time in the city.

The Paraíba do Sul river valley has more than 200 km of sand mining dams, installed more than 70 years ago, which present a perennial risk for all the municipalities nearby. The perception of risk is contextualized in the scenario of urban social vulnerability to water shortage caused by the collapse of these dams because, in the acceleration of mining production, failures in the drainage of the dams or extreme rainfall accumulations could lead to an accident.

Inequalities within the city's territory affect water security differently. Areas of cities with greater and lesser access to services can present an important gradient in water security. Differences in social conditions and infrastructure lead to inequalities in quality of life, vulnerability, and social exclusion/inclusion. These inequalities must be identified to highlight vulnerability drivers and better guide public policies within the city.

Infrastructure accidents that interfere with collecting water for public supply are a potential risk for municipalities that coexist with sand mining dams. Notwithstanding the low severity of the accident, it served as a case study to evaluate local socio-environmental impacts and can be reproduced for cities in similar urban conditions. Economic rises can lead to increased mining activity, with consequent decreases in water security. SUWISVI sought to provide a holistic view of the system to give suitable alternatives for local public policies.

The multi-criteria approach and sensitivity analysis, combined with the use of GIS technologies and remote sensing, sought to collaborate in developing social vulnerability studies that assist in water security and benefit the population.

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General lines to build a model of innovation impact assessment processes addressed to agricultural research organisations

Linhas gerais para construção de um modelo de avaliação de impacto da inovação aplicável a organizações de pesquisa agropecuária

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ABSTRACT

This article is focused on a conceptual model of the innovation impact assessment process, especially directed to agricultural research organisations. This research proposes an existing methodology based on a literature review. The innovative contributions of this article are I. theoretical lines for constructing a model of impact assessment as a base for a future data-based management system; II. a conceptual base of innovation impact assessment process that considers a cross-cut view of sustainability, integrating the environmental, social, policy, and economic dimensions. This article intends to present a theoretical model addressed to research and innovation organisations that will contribute to fulfilling the United Nations' sustainable development goals towards more productive and sustainable agriculture and accomplishing stakeholder challenges and demands.

Keywords: Agricultural Research. Impact Assessment. Innovation. Sustainability.

RESUMO

Este artigo está focado em um modelo conceitual de avaliação de impacto, especialmente direcionado a organizações de pesquisa agropecuária. Baseado em revisão de literatura, suas contribuições inovadoras são: I. linhas teóricas para a construção de um modelo de avaliação de impacto como base para um futuro sistema de gestão; II. uma base conceitual para avaliação de impacto de inovação que leva em conta uma perspectiva transversal de sustentabilidade, integrando as dimensões ambiental, social, política e econômica. O artigo apresenta um modelo teórico aplicável a organizações de pesquisa e inovação em sintonia com os Objetivos de Desenvolvimento Sustentável das Nações Unidas, bem

como buscando uma lógica sistêmica que atenda aos desafios e demandas das partes interessadas da instituição de pesquisa.

Palavras-chave: *Pesquisa Agropecuária. Avaliação de Impacto. Inovação. Sustentabilidade.*

1 INTRODUCTION

Innovation impact assessment is important in adjusting institutional policies and setting research priorities for project leaders, top managers, and their stakeholders.

In this context, agricultural research institutions are imbued to generate innovation for the sector. Initially, verification of how the organisation reaches and impacts its target audiences, how it affects farmer's profits and supply chains, and the degree of benefits it may generate will be necessary. As such, it is important to evaluate the impact severity level and how it affects the environment in farms, the supply chain, and society's quality of life. Positive and negative effects must be evaluated by considering the organisation's health, society, and environment (ASIF *et al.*, 2011, p. 353-367).

After some literature reviews on corporate impact assessment, it was clear that innovation impact assessment methodologies could be increased (ASIF *et al.*, 2011, p. 353-367; BARROS DE MENDONÇA; LAQUES, 2017). We have observed that systemic cross-cut perception sustainability and setting different scales about sustainability components could be introduced. In this respect, according to the Cato (2009, p. 36-37) approach, we understand that the environmental dimension is more important than the social dimension and that this one is more important than the economic dimension. Under a reverse view, if we destroy or mismanage the ecological environment, we are going to weaken the social quality of life that, consequentially, will affect the health of the economy.

As a management tool, it is expected that this proposed new impact assessment model will facilitate technological innovation processes to fit into the sustainability concepts and inserted by a unique managerial system. This innovation conception is expected to help agricultural research organisations better serve the productive sector in producing healthy food for local and global demands. Generating safe food attends the objectives of food security, by enlarging sustainable production processes, according to the parameters established by the World Health Organization (WHO, 2006) and the United Nation's sustainable development goals.

This article is structured in four parts: introduction, materials and methods, results, and discussion.

2 MATERIAL AND METHOD

2.1 MATERIAL

Material is based on a literature review according to the following steps.

2.1.1 THE ROLE OF RESEARCH & INNOVATION TOWARDS SUSTAINABILITY PRODUCTION

Nowadays, organisations must replace their old practices with low sustainability rates with principles, objectives, and guidelines capable of leading to sustainable development. This replacement depends on sustainable innovation. Moreover, this new attitude goes through all types of organisations, an essential condition for it to remain alive in an increasingly dynamic and demanding market environment for social and environmental responsibility (BARBIERI *et al.*, 2010, p. 146-154).

When evaluating research related to agricultural production, it is not enough to assess production processes and outputs; instead, innovation impact assessment is the key point for identifying farmer's, industry's, and consumer satisfaction and improving producer's quality of life, profitability and the effects on the environment, that is, innovation impact assessment goes beyond outcomes. Hence, a major goal of agricultural research organisations has been developing impact evaluation processes (ALSTON; NORTON; PARDY, 1995).

The evaluation must consider *ex-ante* and *ex-post* analysis, focusing on sustainability impacts and considering their continuous improvement - reducing negative and increasing positive effects (CRAIG, 2002, p. 282-311).

Sustainability reports and Social Responsibility reports represent a track to demonstrate how an organisation has been more or less sustainable by appraising the impact of its performance and results on society, the economy, and the environment (BARROS DE MENDONÇA; LAQUES, 2017).

2.1.2 INNOVATION: BASIC CONCEPTS

The Oslo Manual (INSEE, 2016) indicates some innovation categories: product innovation, process innovation, organisational innovation, and marketing innovation. For Planing (2017), an invention must arrive at the market, but that is not enough. Innovation comes from interactions within a collective of actors that allows the mobilisation of different types of knowledge - scientific and non-scientific (BARRET *et al.*, 2018). Social innovations represent new solutions for products, processes, services, technologies, and models, simultaneously meeting a social need (PISANO; LANGE; BERGER, 2015).

"Innovation is the process of making changes to something established by introducing something new. As such, it can be radical or incremental, and it can be applied to products, processes or services and in any organisation" (O'SULLIVAN, 2008, p. 3).

In the present day, integrating sustainability (through its social, ecological, and economic dimensions) in innovation projects becomes an essential condition for attuning to markets and the demands of society (BROOK; PAGNANELLI, 2014, p. 46-62).

2.1.3 IMPACT ASSESSMENT DEFINITIONS

The impact is conceptualised as "positive and negative, primary and secondary long-term effects produced by a development intervention, directly or indirectly, intended or unintended" (OECD, 2002).

The high quantity of terminologies, approaches and analyses on impact evaluation creates a dispersion and disintegration in understanding this issue. They are biodiversity impact assessment; climate change impact assessment; economic evaluation; environmental impact assessment; environmental, social, and health impact evaluation; these represent just some of a long list of approaches to impact evaluation that indicates how large the scope of this issue has become (POPE; ANNANDALE; MORRISON-SAUNDERS, 2004).

However, the above list could be completed by adding a research impact assessment - RIA. According to the International School on Research Impact Assessment, the importance of research impact assessment is growing, and research organisations must meet the requirements of donors who invest in research and expect economic and social returns (ISRIA, 2017).

Many organisations have adopted several ways to evaluate their research impacts, including in the agricultural field, for instance, the Consultative Group for International Agricultural Research (CGIAR),

the Brazilian Agricultural Research Corporation (EMBRAPA, 2015), the Economic Research Service (ERS) of the United States Department of Agriculture (USDA) and the Commonwealth Scientific and Industrial Research Organization for Australian Research - CSIRO (JOLY *et al.*, 2016).

It is possible to identify a template below (Figure 1) that represents a general model of innovation impact assessment, which will serve as the basis for the new and future model to be drawn in Part III of this article. The figure was adapted from Kuby's (1999) scheme and Dowthwaite's *et al.* approach (2003), and it demonstrates a complete systemic vision of impact assessment from the planning phase to the effect phase, which means the stages after an organisation produces its technologies and their absorption by producers and clients as well as its immediate consequences to the economic, social and ecological environment.

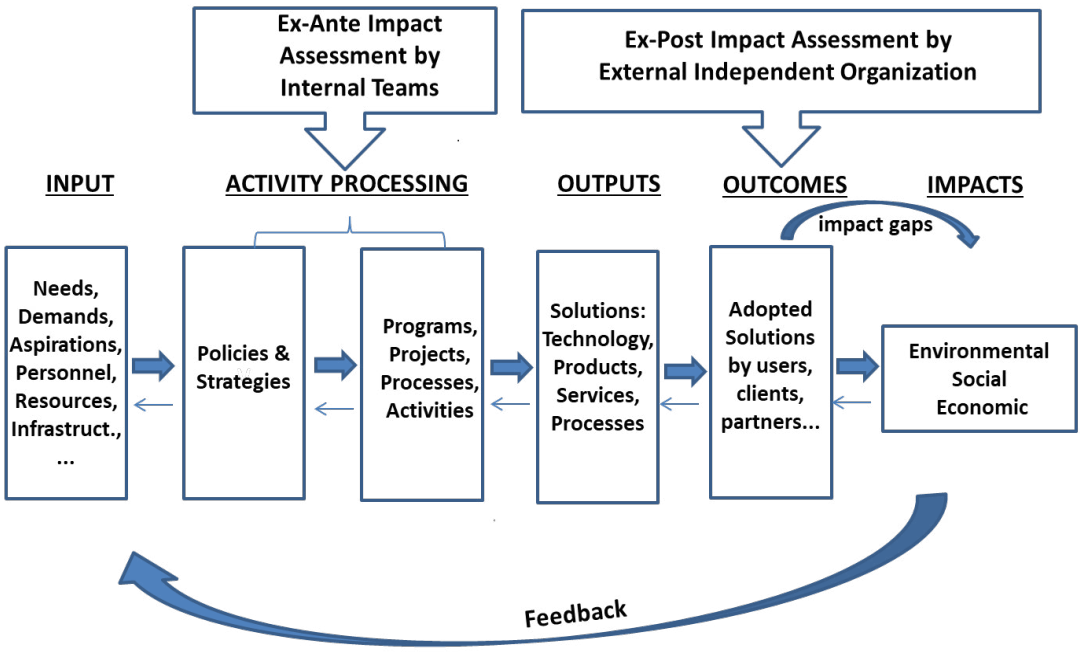


Figure 1 | General Model of Impacts Pathway (Adapted from GTZ Impact Model - KUBY, 1999)

In addition, the effect phase considers the long-term impacts on the economy, society, and environment, which could be named impact gaps and lagged impacts because it is difficult to determine when impacts will happen and whether they will generate simple or complex, direct or indirect effects.

2.1.4 THE IMPORTANCE OF A CONCEPTUAL MODEL FOR INNOVATION IMPACT ASSESSMENT

i) Some Approaches about System, Model, and Conceptual Model

The system can be defined as a set of components that interconnect and interrelate with each other so that their parts form a whole, and this interaction provides some logical purpose, generating final effects over a certain time, with some regularity, forming a network of causes and effects. These components can be objects, equipment, information, people, or even other systems, that is, subsystems. These components can be either fixed or transient. The system has boundaries, and both its internal and external part is called the system's environment (BUCKLEY, 1976, p. 9-68; LAW; KELTON, 1991).

A theoretical model is a hypothetical and theorised reference that analyses a concrete reality and uses it as a baseline for application in the practical world or for developing others (JAPIASSU; MARCONDES, 1989).

ii) Impact Assessment Integrative View: a cross-cut focus

According to Bantilan *et al.* (2014), assessment implies in the quantitative and qualitative analysis, making estimates or valuation and can be focused on four objectives: assessment of the processes; assessment of generated products/services (outputs); assessment of generated outcomes; assessment of generated innovation's impacts to the environment, economic, and society (farmers, industries, services - supply-chain, local, regional and national governments, stakeholders, shareholders, and consumers).

Impacts have three dimensions to be considered (BANTILAN *et al.*, 2014):

- the space scale (local, intra-regional, national, and international);
- the time scale (short, mid, and long-term of effect, as well as passing time or continuous effect), and
- the grade of impact or the intensity scale (low, mid, or high intensity).

All these approaches based on systemic and holistic views give references for a cross-cut focus in the proposed impact assessment model (JAPIASSU; MARCONDES, 1989).

During the impact assessment process, stakeholder participation is essential to guarantee the success of the process and its results (LUYET *et al.*, 2012). This approach has already been demonstrated by the interaction between stakeholder groups, such as civil society, farmers, scientists, and technicians, in rural governance processes (WILSON, 2004).

Despite the search for existing models and, considering the citations of concepts and approaches exposed so far on models of impact assessment of technological innovations, we observed gaps regarding models that consider and deepen the impacts on the following aspects: watersheds; soils; improvement of the quality of life for producer's and their families; farmers profitability; effects on national GDP. We also identified fragile approaches on the impact pathways along the supply chains and, mainly, the absence of indicators that allow a sustainability index from the technological innovations adopted. These and other aspects must be considered in the conceptual model proposed here.

2.2 METHOD

This work adopts a general methodological strategy called "method of development strategy" (CONTANDRIOPOULOS *et al*., 1994, p. 41), which aims to improve some specific technology, which in this article means: the model of innovation impact assessment.

The modelling process started with developing a proto-model based on the literature review, my assumptions, theoretical choices committed to sustainability principles, and achieving an integrated view.

This methodological strategy is presented as a research strategy that aims to use existing knowledge systematically, elaborate a new intervention, considerably improve an existing intervention, or elaborate or improve an instrument, a device, or a method of measurement, including improvements within a qualitative perspective. It means that this proto-model is a pre-conceived framework to support and guide the analysis of the experiences and helps select what should be inspected in each case-study institution during the following steps (CONTANDRIOPOULOS *et al*., 1994, p. 41).

As such, this article is based on a literature review and a critical analysis to reach the final conceptual model of an innovation impact assessment process.

Literature review represents the essential theoretical base as input for enriching knowledge on the recent discussions (from books and papers) towards new information and concepts on impact assessment and associated knowledge, allowing a broader and deeper discussion on the theme. Therefore, a literature review was carried out on impact assessment (economic, social, policy, and environmental), processes of innovation, and sustainability.

3 RESULTS

The concepts described here are already reflections of the summary of a previous selection of several other concepts, which means that the proposed innovation impact assessment model includes the positive aspects of those concepts.

3.1 THE PROTO-MODEL: A CONCEPTUAL BASE FOR AN INNOVATION IMPACT ASSESSMENT PROCESS

The proto-model was developed based on the literature review and, from now on, aims to serve as a parameter for the innovation impact assessment model to be constructed. After analysing four research organisations' innovation impact assessment experiences, the next step is to improve the proto-model, passing by the benchmarking approach to arrive at a model as ideal as possible to be applied by research institutions. The following citations summarise the significant structural aspects for fitting the proto-model framework.

The United Nations Sustainable Development Goals (SDG) show that within the 17 Goals, 7 have a direct or indirect relationship with agricultural activity. Particularly, research and innovation organisations have a key role in reaching SDG 2 (Zero Hunger) and 12 (Responsible Consumption and Production), while food production must be increased by a sustainable way of production (UN, 2015).

To avoid bias in research teams, the impact assessment system must be impartial, driven by independent and external teams, and focus on the impacts pathway (MERGAERT; MINTO, 2015; UNDG, 2011).

The Proto-Model, as shown in Figure 2 below, was developed from the literature review, and it represents the conceptual framework on which the model of the innovation impact assessment management system is supported. The Proto-Model demonstrates that the impact assessment system is an open system, with a high degree of interaction between the internal organisational environment (of the research institution) and the environment, social, policy, and economic dimensions, including stakeholders, clients, and users of innovation's solutions as well as the external environment.

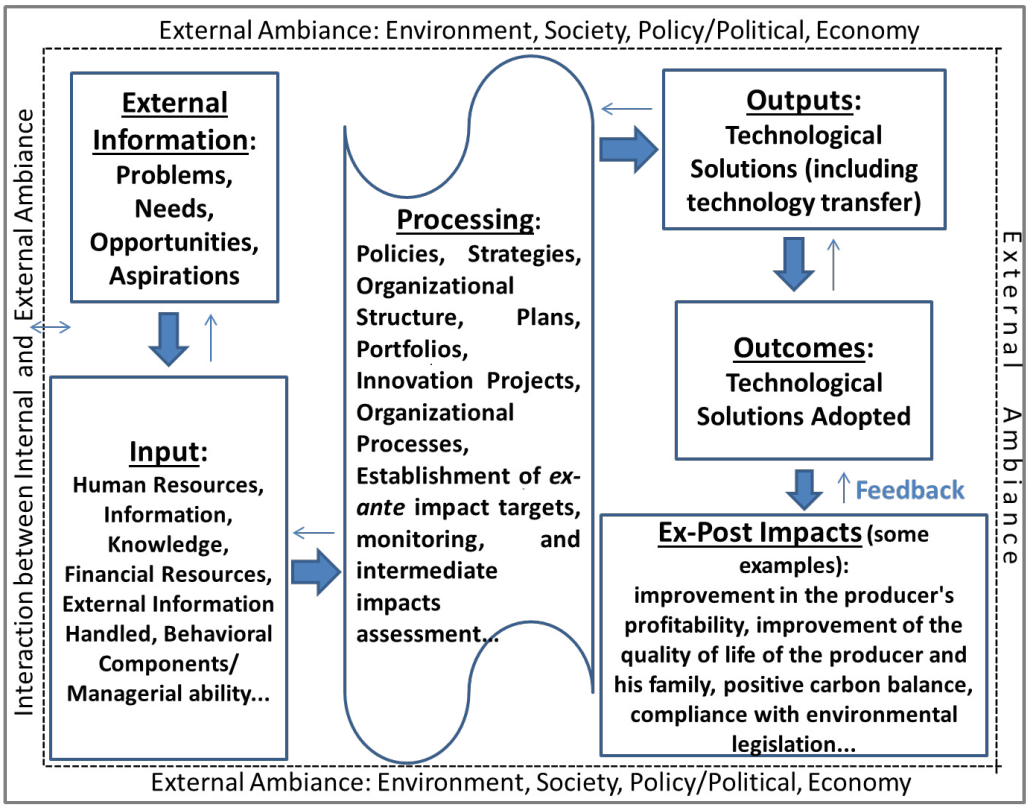


Figure 2 | Proto-Model of Innovation's Impact Assessment Management System (Adapted from Goldstein & Renault, 2004 and Jonkers et al., 2018)

According to Figure 2 above, the proto-model adopts five variables as a structural base which will permeate all stages of the above system (AVILA; RODRIGUES; VEDOVOTO, 2008; BUCKLEY, 1976; CATO, 2009; DOUTHWAITE, 2003; GOLDSTEIN; RENAULT, 2004; JOLY *et al.*, 2016; JONKERS *et al.*, 2018; KUBY, 1999; LAW; KELTON, 1991; MARKUS; MAJCHRZAK; GASSER, 2002; METHERBE, 1986; RODRIGUES *et al.*, 2010):

3.1.1 CONNECTION WITH INSTITUTIONAL POLICIES AND STRATEGIES

The information and signals from the external environment should guide the construction of policies and institutional strategies. In the scope of these, the impact assessment system must be included as an institutional priority.

3.1.2 THE EXISTENCE OF A FRAMEWORK TO EVALUATE THE INNOVATION'S IMPACT

It is essential for the research organisation to have a structure to manage the innovation impact assessment process, preferably driven by a permanent structure. A stable or permanent structure is a way to avoid discontinuities in actions.

3.1.3 CONNECTION WITH THE INNOVATION PROCESS OF THE ORGANISATION

By aiming to monitor the innovation process step-by-step, the impact assessment system must be coupled with the innovation system, allowing course adjustments throughout the innovation process.

3.1.4 ADOPTION OF SUSTAINABILITY CONCEPTS BY A CROSS-CUT VIEW

Integrating the economic, social, policy, and environmental dimensions is necessary. It is important to make an integrative analysis among all socio-economic and environmental dimensions, understanding that there are different values among them (with their respective classification of importance – CATO, 2009, p. 36-37).

3.1.5 PROCESS ANALYSIS FOCUSING ON THE IMPACT'S PATHWAYS AND EX-ANTE/EX-POST ANALYSES

To assess innovation impacts means monitoring every step of the innovation process, starting with the stages of identifying the demands and needs of clients and stakeholders. The extension of steps should contemplate from an ex-ante impact assessment to post-innovation impact generation over time (ex-post impacts), including impact delays, in society, the economy, and the environment.

3.2 INTRINSIC RELATIONSHIP BETWEEN THE OPEN INNOVATION AND THE PROTO-MODEL

Consistent with innovation characteristics and impact assessment in continuous interrelationship with stakeholders and all components, directly and indirectly, influential in generating solutions.

A research organisation can generate technological innovation, product innovation, process innovation, organisational innovation, service innovation, and marketing innovation (DIEZ, 2001; THOMPSON; LINDAHL, 2013, p. 277-288). Global quickness requires systemic reading, in a dynamic and complex environment, in non-linear processes of innovation (GREENACRE *et al.*, 2012). It is essential that an invention can arrive at the market, but this is not enough. A feedback loop and a close relationship with the needs and desires of society are also required and denote that innovation is important, while these factors will depend on the impact analysis, sustainability warranty, and longevity (PLANING, 2017).

The organisation that adopts the model of innovation's impact assessment management process designed in this article must implement an open innovation platform to support the *ex-ante* and *ex-post* impact analysis (CHESBROUGH *et al.*, 2006). This platform has to be operated by a whole, and integrative management system based on the proto-model here considered, which requires a dynamic interaction with its stakeholders throughout the entire innovation process.

4 DISCUSSION – PROPOSED CONCEPTUAL MODEL

4.1 GENERAL OVERVIEW OF THE MODEL

The Conceptual Model of Innovation's Impact Assessment Process – IAP designed here is especially directed to agricultural research organisations and is focused on the ex-post impacts.

This article does not pretend to undergo comparative analysis nor to identify and critically delve into the positive and negative points among the theory sets studied, but intends to focus on the new impact assessment model developed, as well as on its structure and operational components. This model is also the result of my academic training and professional experience.

Synthetically, what is the purpose of assessing impacts, and what is their main focus?

IAP can reach a large spectrum of purposes and audiences, but it is mainly directed to a synthesised group of objectives. It means considering the four impacts intentions (ISRIA, 2017):

1. Accountability (to be transparent, comply with demands to oversight bodies and supervision of public resources and society in general);

2. Allocation (to be an instrument of governance and management for an organisation's managers);

3. Analysis (to be an internal team instrument of continuous improvement of the impact assessment process and innovation process, by a cross-cut view of sustainability); and

4. Advocacy (to demonstrate the importance of innovation for stakeholders).

4.1.1 WHAT IS THE IAP MODEL?

IAP is a management tool in support of decision-making. By means of feedback on the impacts that innovations cause and listening to its stakeholders, it helps to adjust policies, strategic plans, priorities, research, and innovation projects.

IAP is a base for a system that visualises and coordinates *ex-post* assessments addressed to the social, policy, economic and environmental dimensions. The system is based on the impact pathway, which is coupled with the innovation process course. And it tracks the various space and time scales, considering the time-delayed impact.

IAP is composed of several parts by interrelating, interacting, and inter-influencing among them. This general theory of systems is the groundwork that will guide the general concept of an impact assessment system as well as a proposed open innovation model (BERTALANFFY, 1968; BUCKLEY, 1976; JAPIASSU; MARCONDES, 1989).

4.2 DEFINING INNOVATION BY THE IAP APPROACH

As mentioned previously, an innovation impact assessment model must be coupled to the innovation system because the evaluation will measure the impacts of what the research organisation produces for its stakeholders, market, and society. Thus, focusing on the ultimate goal of this article, it is essential to understand the concept of innovation, its types, its characteristics, and its architecture in the context of IAP.

By synthesising and within the IAP and open innovation context: innovation is the outcome effectively acquired, transferred, and absorbed by the users and clients resulting from the interaction, tuning, and continuous exchange between stakeholders and the research organisation (BROOK; PAGNANELLI, 2014; CHESBROUGH *et al.*, 2006; CHRISTENSEN *et al.*, 2015; INSEE, 2016; O'SULLIVAN, 2008; PISANO; LANGE; BERGER, 2015; PLANING, 2017).

4.3 IAP AS A TOOL FOR MANAGEMENT - ITS OPERATIONAL COMPONENTS

4.3.1 IAP AS A TOOL FOR MANAGEMENT

In this article, management represents the process of internal driving of the research organisation, with appropriate structure, processes, resources, and staff, by answering with efficiency, efficacy,

and effectivity the governance and external environmental demands/aspirations and needs. Then, IAP is a managerial tool for helping managers construct and adjust priorities of research & innovation, leading innovation projects and processes of innovation support in an agricultural research organisation.

4.3.2 IAP COMPONENTS

IAP consists of the following components: Principles, Values of the Impact, Defining Impact Dimensions, Impact Indicators Parameters, Nature of the Impact or Impact Classification, Impact Characteristics, Impact Intensity, Impact Scales, Level of Impacts, Frequency of the Impact, and, Impact Relevance.

4.3.3 IAP GENERAL PRINCIPLES

i. IAP must be connected with the institutional policies and strategies, and will be aligned with United Nations Sustainable Development Goals, in particular, 2 and 12;

ii. IAP must be in connection and with synchronicity with the innovation process of the organisation;

iii. IAP will adopt the process analysis focused on the impact pathway;

iv. IAP must adopt sustainability concepts from a cross-cut view by integrating economic, policy, social, and environmental dimensions.

4.4 VALUES OF THE IMPACT

Impacts Have Tangible Values and Non-Tangible Values (Worth). There are measurable and non-measurable values. The mathematical vision cannot measure some impacts because they are beyond economic values or not based on quantitative environmental measurements. Economic values are measurable, while cultural and social values cannot be measured because they are intangible. They can be immersed in an extensive complexity, as in the case of biodiversity in general (within a diffuse, complex, and broad ecosystem context).

4.5 DEFINING IMPACT DIMENSIONS: ENVIRONMENTAL, SOCIAL, POLICY, AND ECONOMIC

Environmental impacts are all those that affect the internal and external environment of the property where a particular solution was adopted, which means several spatial scales are directly or indirectly affected by the use of such a technological solution. For example, the carbon balance resulting from the use of the solution, which can directly affect the global climate; the use of certain chemical products that can directly affect the physical quality of the soil of the farm, and indirectly the chemical and biological quality, as well as the groundwater table.

Social Impacts can be understood as all effects arising from a solution that affects the local, state, national and global social environment within productive arrangements or supply chains, quality of life, nutrition and health, and well-being (The author).

Policy Impacts as a structural approach refers to public policies, such as economic policy, tax policy, social policy, health policy, environmental policy, etc., and all its derivatives, that is, plans, programs, projects, and activities.

Economic Impacts can be understood as the production technology affecting the farmer's production and hence generating positive or negative impacts on his economy (for instance: improvement of his profitability, improvement in the purchasing capacity of inputs for his production). Another form of economic impact is the reflexes on the supply chain and its consequence on GDP (Gross Domestic Product).

4.6 IMPACT'S INDICATORS PARAMETERS

By measuring impact, it is necessary to establish indicators and parameters related to the previous situation and after a technological solution has been adopted. This comparative analysis will establish the difference between the two moments: before and after a technology has been adopted by the farmer or by the productive sector.

4.7 NATURE OF THE IMPACT OR IMPACT CLASSIFICATION

The impact manifests itself in several ways. IAP classifies the nature of impact in: i) quality; ii) types; or timing.

4.7.1 THE QUALITY OF IMPACT CAN BE DEFINED AS POSITIVE OR NEGATIVE.

4.7.2 THE TYPES OF IMPACT ASSESSMENT OR THE TIMING OF IMPACT ASSESSMENT

Are expressed by two moments: *ex-ante* and *ex-post*. *Ex-Ante* Impact represents the planning phase in which a scenario exercise is carried out along the impact pathway on what may occur during the execution of the innovation stages. For that matter, the model proposed here is only focused on the "*ex-post*" moment. The *ex-post* impact assessment happens after the research organisation generates the outcomes.

4.8 IMPACT CHARACTERISTICS

It can be intended or unintended; intermediate or final. Before arriving at the producer, a technological solution undergoes tests and validation. However, it is possible that it may generate unintentional or unexpected impacts when arriving in the field, and on a large-scale basis. Unintentional impacts can also be considered externalities, that is when a solution is adopted, and it generates undesirable or even desirable effects that were not foreseen on the third party (for example, on the economy, society, or the environment).

Intermediate impacts occur during the various stages of the innovation process before it reaches its final outcomes when it will be subject to the last appraisal stage. According to the outcomes, the final impact evaluation begins, that is: the ex-post stage of impact evaluation is initiated until reaching the stages of impact unfolded assessment, which can reach different supply chains over time.

4.9 IMPACT INTENSITY

The impact intensity represents the strength level or intensity of impact, whether low, medium, or high intensity.

With the use of a scale ranging from -3 to +3 it will be possible to merge two impact characteristics: the level of intensity and the quality of the impact. The scale will be -3 the most negative, -2 the average negative, -1 the least negative, the 0 level (without relevant negative or positive impact), +1 with a low positive impact, +2 the average positive impact, and +3 with a high positive impact.

4.10 IMPACT SCALES

The impact scale concerns the extent of the impact, which has two dimensions: time and space. From a timescale perspective, there are short, medium, long, long-term, and perennial impacts. In this component, it is necessary to consider lag impacts, which means the impact length along the time: many impact types can delay causing gradual effects on the economy, policies, society, or environment over time.

A short-term impact occurs immediately within a year. The medium-term impact is more than one year, up to five years. The long-term impact is more than five years, up to twenty years. The extreme long-term impact is over 20 years and limited to 100 years. A perennial or persistent impact means an impact that may persist continuously for over a hundred years. During the impact assessment process, it is essential to consider the type of technological innovation generated. Some solutions will only generate effective impacts after 20 or 30 years, as in the case of forest technologies linked to noble species; while others reach the peak of their effects at the age of 5, such as those related to vegetables or grains. And these positive or even adverse effects can last for many years.

The impact from a spatial scale perspective means the geographic space where the effect of a product or service takes place (the reflexes of an adopted technological solution). It can be local space (inside the farm); municipality space; state or regional space; country space, and international space (or even global space). Usually, local impacts are impacts inside the farm which directly impact the environment, social aspects, and the economic components related to the production factors of the farmer (for example, profitability addition, an improvement in the quality of health & education).

4.11 LEVEL OF IMPACTS

They can be direct, indirect, and unfolded.

The direct impact is the direct effect on someone or something. Usually, direct impacts happen on the direct users of a certain technological solution. It is the direct effect on a farm and his/her owner, causing economic and social reflexes, including in the environment.

Indirect impacts are those arising after direct impacts. Normally, indirect impacts occur on indirect users.

The unfolded impacts are those with successive effects in supply chains, different from those initially related to the product generated with the use of a certain technology. That is, after a given technology generates direct and indirect impacts on specific supply chains, respectively. According to expectation, those indirect impacts can generate other different impacts on other supply chains, which were not previously expected. They can be called tertiary impacts, which may arise in the short, medium, or long term. It is important to emphasise that these tertiary impacts should be measured by the impact

assessment model in the economic, policy, social, and environmental dimensions of different supply chains or businesses that can be generated according to the time elapsed.

4.12 FREQUENCY OF THE IMPACT

Impact frequency is an important measure for discerning risks and levels of harm to those potentially or affected by the impact. This measure should serve as a parameter for decision-making for corrective actions when negative impacts are identified or redefine priorities of policies and projects or reinforce positive impacts through renewed strategies. The frequency can be: Constant; Recurring (Intermittent); One-offs; Variable and Inconstant; or, Unpredictable.

4.13 IMPACT RELEVANCE (ON PEOPLE, SECTORS, OR ENVIRONMENT)

Frequently, an impact does not deserve so much concern because of its low relevance, or at least it requires less focused attention compared to others that are more impactful. Thus, a high-relevance impact (or even medium-relevance impact) should deserve attention and preventive measures, as well as corrective or minimising measures. The relevance classification is a benchmark for decision-making prioritisation for intervention or preventive action. The impact relevance depends on the vision or feeling of who is potentially affected, whether it is a public, a productive sector, part of society, or representatives of environmental interests (scientists and environmental activists, for instance).

Based on the literature studied and the author's experience, for this article, we set the following definitions: economic represents the productive sector in general or specific segments of producers, industry, commerce, and supply chains; policy means the policy-makers, government institutions, parliament, judiciary; social considers local, regional or national populations, specific social groups, families of producers, and traditional populations.

Relevance from the perspective of stakeholders and the economic, policy, and social sectors:

1. High-impact relevance for all stakeholders and sectors
2. High only for some stakeholders or sectors
3. Medium for all
4. Medium for some stakeholders or sectors
5. Low for all
6. Low for some stakeholders or sectors

To the environmental dimension, the impact relevance will be measured according to the following indicators (the environmental affected component must be specified): High; Medium; or Low.

4.14 THE MODEL OF RESEARCH & INNOVATION'S IMPACT ASSESSMENT PROCESS - IAP

Inspired by the General Model of Impacts Pathway, Figure 1 (Adapted from GTZ Impact Model - KUBY, 1999) and in the proto-model cited in Figure 2, the following Figure 3 demonstrates the core of the

article by presenting the summarised model of the Impact Assessment Process, showing the general impacts and interrelationships among its elements, indicating the basic process flows.

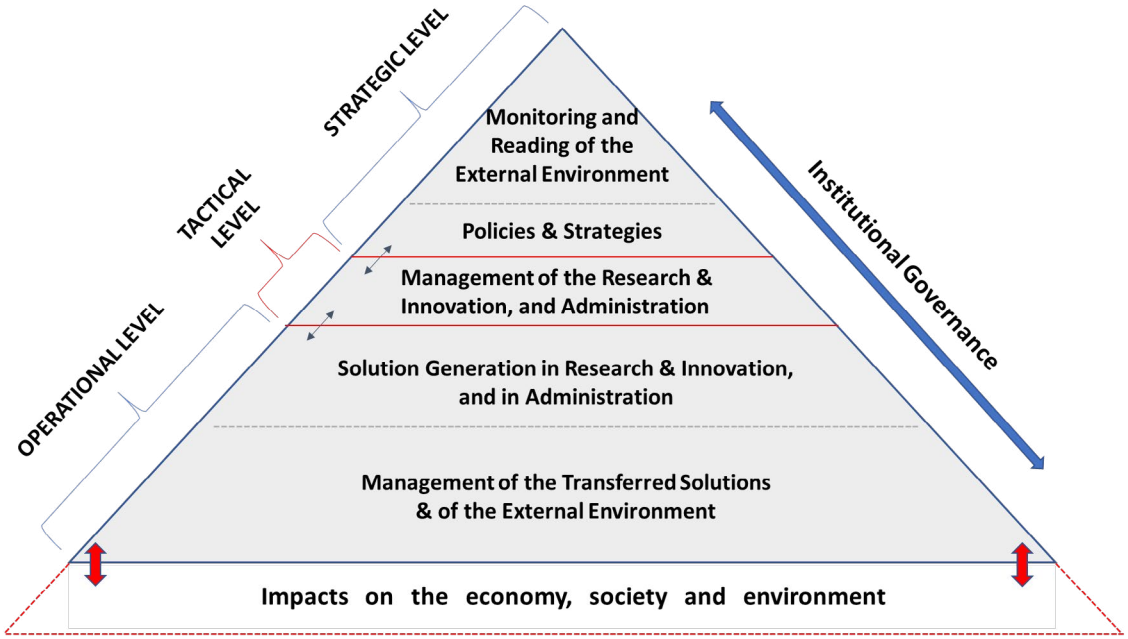


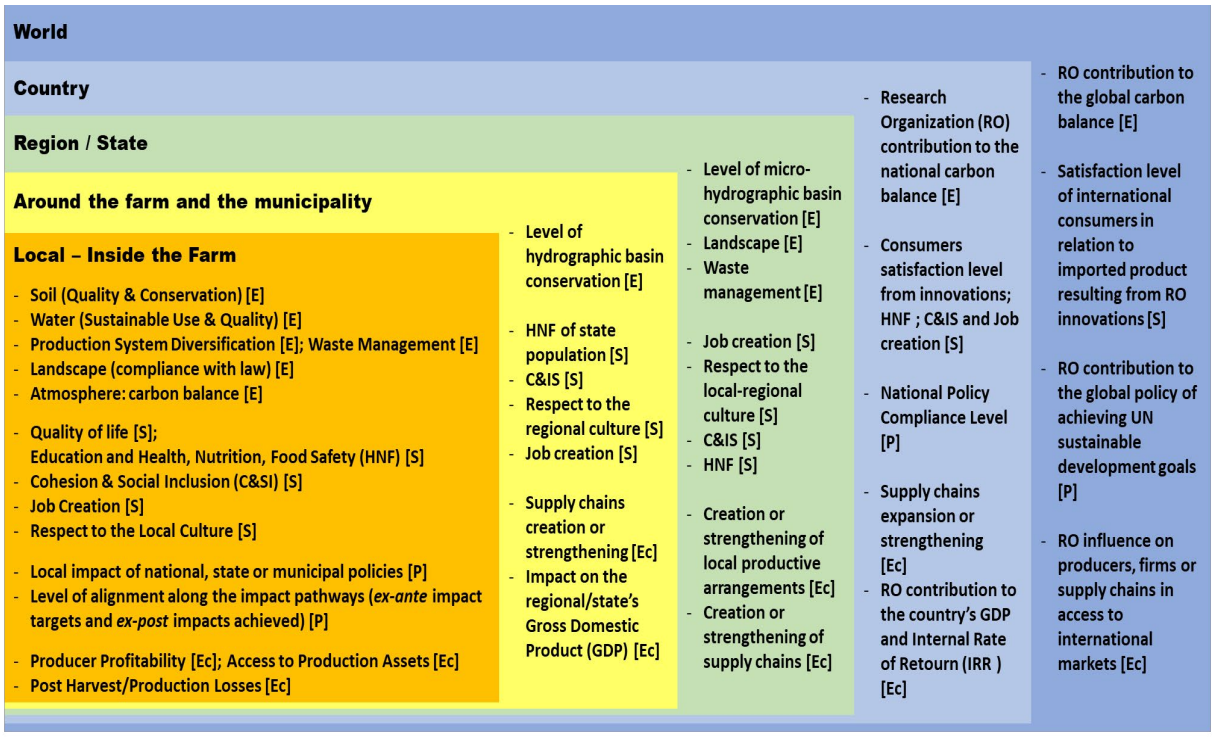
Figure 3 | Summarised model of the impact assessment process

Source: The author.

The impact pathways happen within the research organisation (even if there is interaction with the external environment), generating intermediary impacts, and outside the organisation, generating direct, indirect, and unfolded impacts, where the pathways are more complex and, therefore, by requiring more comprehensive and complex approaches regarding monitoring and evaluation.

This monitoring and evaluation should include environmental analysis from the economic, policy, and social context and involve as many stakeholders as possible, which should be classified in order of importance versus direct or indirect influence on the organisation, as well as its outputs and outcomes. These measures will be reflected by the quality and degree of organisational sustainability.

We can observe in Figure 4 below the continuous flows among all stages of the innovation pathway, demonstrating the interdependence and interaction among their components. It is also clear that the impacts along the course of innovation and along the supply chains, which may affect to a greater or lesser degree the different members of the external environment (stakeholders, users, customers), as well as the environment itself, with repercussions on society and economy.



E=Environmental Dimension; S=Social; P=Policy/Political; Ec=Economic

Figure 4 | Impacts Through the Five Spatial Scale Perspective

Source: The author.

Each zone above demonstrates environments or spaces and their components along the supply chain, from the local level (within the property) and its surroundings, going from the national scope to the international environment. Thus, the proposal is to assess the impacts along these zones.

The impact assessment process is divided into zones (from 1 to 5), these are separated by different coloured blocks that demonstrate different spatial scales, which means that the flow towards *ex-post* impacts is a consequence of the farm's internal management processes to the stages in which external parties, along the supply chain, are affected by a given technological solution (following the impact pathway). These blocks contain a series of smaller processes, sub-processes, and activities, which will not be detailed here, a measure applicable in the case of an IAP operational manual. Still under the basic concepts of the general systems theory, the IAP Model is subdivided into three major levels: strategic, tactical, and operational, respectively.

Figure 4 above also presents the categories of impact indicators at each level of the spatial scale, with the first degree of direct impact on the property or at the local level (within the farm or industry that adopted the technological solution generated by the research body) and from this local space the flow proceeds to larger spatial scales. From this centre of impact, the displacement occurs towards the borders, that is, the scale is expanding, passing through the neighbourhood of the local property and covering the entire area of the municipality where it is located. Then, the impacts reach the state unit of the federation, next, they reach the geopolitical region and finally reach the national level. As the product generated by the property enters the supply chains that reach markets in other countries, the impact is moving internationally and globally.

The spatial scale, therefore, has a direct relationship with the degree of data and information added, going from the most detailed to the most aggregated, respectively, from Zone 1 to 5, and this logic will be reflected in the reports that will consolidate this scale. Zone 1 of the spatial dimension represents the local space within the property. Zone 2 is the space within the municipality where the property is located. Zone 3 is the state of the federation where the municipality is located. Zone 4 is the country's

space. Zone 5 is the international space or global area. The model establishes a cross-section of the indicators through the various spatial scales, going from the most detailed, within the property (local level), through the municipal level, where there is a little more aggregated information. Thus, in the sequence, the data and information are further aggregated at the state and national level, respectively, and finally, more summarised at the international or global level, seeking to reduce the information to a few essential indicators.

When analysing the sustainability dimension (economic, policy, social and environmental), as well as their respective components, attributes, and indicators, a larger set of items can be seen in the environmental and social dimensions of the local scale, and fewer items on the policy and economic issues. It is because environmental risks may generate irreversible local impacts or an unfolding sequential process of adverse effects on society and the economy, considering the principle of transversality.

On the other hand, it is necessary to emphasise the high degree of depth and impact expressed in policy and economic components descriptions. Furthermore, these indicators are levelled when analysing state, national and global scales. And yet, when calculating the sustainability balance of a technological solution, it is necessary to consistently apply the weighted average as a way of equalising these differences.

It is important to emphasise that it will be important to quantify the impact of sustainability through a sustainability index. The calculation to arrive at this index may result from adopting specific weights for each dimension (economic, environmental, social, and political). The result of the sustainability index measured for the adoption of a certain technology should be the subject of future research. A measurement summary of sustainability indicators can be seen below.

All indicators will adopt a measurement scale varying from -3, on the most negative impact, to +3, on the most positive impact, being "0" for cases of unchanging the case of neutral impacts. To target a more accessible approach for the comprehension of the indicators by society at large, it is possible to convert the values obtained into general concepts, such as: -3 = extremely negative; -2 = very negative; -1 = negative; 0 = neutral, unchanging or no significant change; + 1 = positive; + 2 = very positive; + 3 = extremely positive.

Figure 5, the conversion table below, demonstrates the correspondence of each impact indicator.

-3 Extremely Negative	-2 Very Negative	-1 Negative	0 Unchanging (Neutral)	+1 Positive	+2 Very Positive	+3 Extremely Positive

$$\frac{\text{[Economic] + [Political/Policy] + [Social] + [Environmental] Dimension}}{\text{Sustainability Function (SF)}} = \boxed{\text{Sustainability Balance}}$$

Figure 5 – Sustainability Scale for Measuring IAP Indicators

Source: The author

Figure 5, above, also displays the Sustainability Balance, which represents the sustainability indicator of an innovation's solution generated by the research organisation. It is the weighted average of the respective indicators. SF is the sustainability function, represented by the sum of the weight of each dimension.

During the practical assessment process, some indicators will be according to data collected from each zone, as presented in Figure 4.

5 CONCLUSION

By studying the bibliographic references and adding my training and professional experience related to impact assessment, except for some failures to identify more complete approaches in the market, I realised the need for a more systemic, cross-cut, and integrated management approach to impact assessment. From this perspective, the proposal presented here emerged, which seeks to propose general lines for constructing an impact assessment process of innovation applied to agricultural research organisations, having as a central point Figure 4, which focuses on the aspects of data collection and measurable information to dimension the sustainability level of adopting a certain technology on a farm.

This article does not intend to exhaust the subject, and we are aware of the broad spectrum that the subject covers, requiring further investigation, especially to dimension the indicators that will measure the sustainability index of a particular farm and consequently of the tested technological innovation, considered in the 5 zones presented in the model, along the supply chain.

The main result expected from the effective operation of the model of innovation's impact assessment process is to support organisational governance and management by positively influencing towards continuous improvement of innovation policies and strategies, as well as to set priorities for research projects. It will be operated through the feedback of the system that should help the organisation achieve growing sustainability in its solution production so that agricultural systems and its supply chain can be increasingly sustainable, thus meeting the United Nations' sustainable development goals, with a special focus on meeting goals 2 and 12.

The world needs to reduce social inequalities, eliminate hunger and sustainably expand food production. Agricultural research organisations are key players in this scenario and need to be directly aligned with those needs, already validated by the United Nations.

Most agricultural research organisations worldwide are already seeking to internalise the UN's sustainable development goals. Thus, evaluating the impact in the economic, policy, social and environmental field of its research and, therefore, of its innovations. becomes fundamental in the pathway of the growing search for the sustainability of the countries and the planet.

From this perspective, proposing the improvement of the impact assessment processes was an important product of this article as a way of contributing to the efforts towards sustainable development, as well as supporting the decision-making processes of research organisations, especially from the agricultural sector. IAP intends to support the redefinition of priorities for research innovation in response to the expectations of its stakeholders.

Reports generated by IAP will be useful for strategic, tactical, and operational decision-making processes, providing subsidies to adjust policies, plans, programs, processes, projects, products, and services, aiming at a more sustainable production.

To apply IAP, it is essential to prepare an operational guide capable of translating each step to the real world, with methodological details, including specifying the executive management framework of the whole process.

Finally, by viewing sustainability for the agriculture sector as based on SDGs driven by the UN, the IAP presents a novel contribution as a differential in relation to what exists on impact assessment oriented to support agricultural research and innovation policies and strategies by the institution: the approaches

considered in Figure 5 (with the sustainability balance formula) and Figure 4 with its various considerations, for example: a proposal to focus on the impacts along the entire supply chain that will adopt a certain technological solutions, as well as special attention on sustainability impacts within and around the property, paying attention to: the impacts on the soil; watersheds; productive landscape (level of diversification); carbon emissions (environmental focus); improvement of the farmer's and his family's quality of life (social focus); level of the farmer's profitability; and, effects on national GDP (economic focus).

The next step will be to test this conceptual model and validate it. Making this Model functional implies elaborating an operation guide, which should be the next step of this project to be developed.

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Public Policies and Adaptation to Climate Change: Three Case Studies in the Brazilian Semi-Arid Region

Políticas públicas e adaptação às mudanças climáticas: três estudos de casos no semiárido brasileiro

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ABSTRACT

Adaptation to climate change, understood as the moderation of sensitivities and the strengthening of adaptive capacities modifies the conditions and, consequently, the impacts of climate change on vulnerable populations. On the other hand, adaptive capacity depends on public policies tailored to different groups' social, economic, and environmental realities. This article discusses specific vulnerabilities, adaptive measures and opportunities identified through semi-structured interviews and participatory workshops in three groups with different socio-environmental profiles: the Fundo de Pasto (FP) traditional communities in Northern Bahia, the Tuxá indigenous community in Rodelas/BA and the irrigated perimeters of the Juazeiro/BA-Petrolina/PE pole. These case studies confirm that adaptation is strongly conditioned by the physical characteristics of the region where the population is located (such as rainfall levels and proximity to perennial water bodies, which condition "risks"); but that it also depends on a wide range of social, economic, cultural, and political factors.

Keywords: Adaptation. Climate change. Public policies. Semiarid region. Brazil.

RESUMO

A adaptação às mudanças climáticas, entendida como moderação das sensibilidades e fortalecimento das capacidades adaptativas, modifica as condições e consequentemente os impactos do clima nas populações vulneráveis. Por outro lado, a capacidade adaptativa depende de políticas públicas adequadas à realidade social, econômica e ambiental. Nesse contexto, o presente artigo discute vulnerabilidades específicas, medidas adaptativas e oportunidades identificadas por meio de entrevistas semiestruturadas e oficinas participativas em três grupos de diferentes perfis socioambientais: as comunidades tradicionais de Fundo de Pasto (FP) no norte da Bahia, a comunidade indígena Tuxá em Rodelas/BA e os perímetros irrigados do polo Juazeiro/BA-Petrolina/PE. Os estudos de caso confirmam que a adaptação está fortemente condicionada às características físicas do local em que a população se encontra (como o regime de chuvas e proximidade de corpos hídricos perenes, fatores que condicionam o "risco"), mas que também depende de uma ampla gama de fatores sociais, econômicos, culturais e políticos.

Palavras-chave: Adaptação. Mudanças climáticas. Políticas públicas. Semiárido. Brasil.

1 INTRODUCTION

Climate change is one of the main challenges for global environmental governance in the 21st century. These risks are being addressed on two fronts. The first, called *mitigation*, acts on the drivers of climate change by reducing (mitigating) the concentrations of greenhouse gases. The second front, adaptation, brings together efforts to mitigate the already inevitable impacts of climate change and manage present and future vulnerabilities.

Initially treated as a separate issue from the environmental political agenda, since the 2000s, climate change adaptation has emerged as a cross-cutting theme in sustainable development (SD) (ADGER *et al.*, 2009; LAHSEN *et al.*, 2010). More recently, it was incorporated by the UN into the Sustainable Development Goals - SDGs[1]. In Brazil, adaptation was institutionalised in the National Policy on Climate Change - PNMC[2] and, in 2016, a specific government plan was created to address the topic, the National Adaptation Plan[3], aiming at its consideration by sectoral agendas. The increasing internalisation of adaptation in the political process has been demanding from the scientific community theoretical and analytical frameworks capable of providing operational concepts and methods of analysis that dialogue with decision-making. In this sense, different frameworks have been proposed, from which we highlight the *vulnerability* framework employed by the Intergovernmental Panel on Climate Change - IPCC and the *resilience* one.

The approach to vulnerability, which originated in Geography, has different proposals for theoretical and conceptual frameworks, but those that have acquired greater popularity are those synthesised by the IPCC. In its 2014 AR5 report, the IPCC brought a framework of vulnerability slightly different from the ones adopted until then (OPPENHEIMER *et al.*, 2014). It identifies vulnerability as the predisposition or propensity of a system to be adversely affected by a *hazard*. *Hazard* refers to a physical event, natural or human-induced, with the potential to cause loss and damage to ecosystems and human systems and the ecosystem services they depend on. Another critical concept is *exposure*, which describes the presence of social-ecological systems in shapes and areas that may be adversely affected (OPPENHEIMER *et al.*, 2014).

Vulnerability is determined by the confluence of different socioeconomic, environmental, and institutional factors, synthesised in two concepts by the IPCC: *sensitivity* and *adaptive capacity*. The first refers to the internal characteristics of the systems with which the *hazard* interacts in determining the magnitude of the adverse effect (LINDOSO, 2017). The second, on the other hand, refers to the capacity of systems, institutions, people and other organisms to adjust to potential adverse effects, seize opportunities or respond to concrete climate impacts (IPCC, 2014). As of AR5, the risk approach has gained significant relevance in the IPCC, whose concept is understood as a function of exposure, vulnerability and probability of *hazard* occurrence, thus functioning as the organising element of the conceptual and analytical framework (OPPENHEIMER *et al.*, 2014).

Despite AR5's focus on *hazard*, there are approaches in the literature on socio-environmental vulnerability that place greater emphasis on social, economic, political, and historical-structural factors as sources of pressure on specific population sectors (GALLOPÍN, 2006; VALENCIA, 2016). Such approaches do not employ vulnerability as the linear consequence of the incidence of a physical risk (the *hazard*) on a group but understand it as a circular and multidimensional process (O'BRIEN *et al.*, 2007). In this sense, institutional, socioeconomic and biophysical factors make up the contextual conditions that determine vulnerability. These conditions affect and are affected not only by physical risks and events but also by social, economic and political structures and changes.

The framework of resilience, in turn, has its roots in ecology. It is a concept employed in the climate change literature to describe the capacity of social-ecological systems to undergo disturbance, maintaining their basic structure, functions and identity through learning, reorganisation and development (IPCC, 2014; NORBERG; CUMMING, 2008). It is often used as a synonym for adaptive capacity in the climate change literature (LINDOSO, 2017).

In the vulnerability approach, climate adaptation is understood as moderating sensitivities, reducing exposure and strengthening adaptive capacities. This approach focuses on understanding contexts that condition the vulnerability of social-ecological systems (LINDOSO, 2017). In the resilience approach, adaptation is used to describe resilience building. This approach focuses on understanding these systems' response processes (LINDOSO, 2017). In a context where a variety of factors, including structural ones, limit the ability of social-ecological systems to adapt, response processes such as learning, reorganisation and development are as relevant as the context that determines the response.

There is, therefore, a convergence of the two theoretical and conceptual frameworks. In this context, the socio-ecological systems perspective is a favourable epistemic space for interdisciplinary encounters (BINDER *et al.*, 2013). It is dear to both the resilience and vulnerability approaches and has its analytical relevance in recognising that the dynamics of human and natural systems establish inextricable relationships (GALLOPÍN, 2006; TURNER *et al.*, 2003). Separating them into isolated analyses can produce misleading results.

This same understanding is shared by the Nexus approach, which is gaining significant prominence in the SDGs policy agenda and has a great interface with climate change adaptation - and mitigation efforts (LINDOSO *et al.*, 2018; RASUL; SHARMA, 2015). The Nexus approach adopts mainly, but not exclusively, the perspective of three securities: water, food and energy, always taken together. The innovation of the approach lies in the relationships of *trade-offs* and synergies between the silos, thus placing great emphasis on the policy-institutional and normative dimensions (KURIAN, 2017). Nexus critics are wary of the approach's ability to be operative, as it still lacks conceptual and methodological consensus (GALAITSI *et al.*, 2018), while its proponents argue that this flexibility is what makes the approach interesting within a scientific and policy context grounded in different areas of knowledge and agendas (BROUWER *et al.*, 2018).

One region that has deserved attention due to its complexity and the possibility of greater evidence of the water security component articulated with the others is the São Francisco River Basin, especially in its Submédio (Middle) section. The main *hazard* to which the region is subjected is rainfall variability. The SSF is inserted in the Brazilian semiarid region, which faces a dry climate and low precipitation, and has prolonged droughts as an important exposure vector. Recently, the region has been exposed to one of the most intense drought periods. In the SSF, in 2010, there was a strong reduction of the Rainfall Anomaly Index (CAI[4]), and between 2012 and 2016, the CAI remained negative, in most years below -2, indicating a very or extremely dry climate (SOBRAL *et al.*, 2018). Despite this, the São Francisco River that runs through the area enables different water availability and access dynamics.

Furthermore, the distinct groups and sub-areas of the HFS have, on the one hand, contextual vulnerability factors in common as they belong to the same region with specific physical, cultural and historical features. At the same time, there are many differences in the contexts of the vulnerability of these groups, as social, economic and political processes and even geographical location have outlined contrasts between them. Especially since the development and modernisation policies of the 1960s to 1980s, the HFS has changed and become more heterogeneous. The formation of the public irrigated agricultural perimeters and the Petrolina and Juazeiro agro-industry hub, as well as the energy ventures on the São Francisco River, gave rise to new sub-groups benefiting from the projects, new inequalities and altered the dynamics of the region (ANDRADE, 1984; ARAÚJO, 2000; BURSZTYN, 2008; SCOTT, 2009).

The sensitivities and adaptive capacities of communities living in the SSS are quite different and concern several dimensions, such as land, water, food, work, income, health, migration and mobility, and vary according to the condition of each social group. However, some indicators can provide a perspective of the general socioeconomic conditions under which the population of the Submédio was exposed to the recent drought period. The Firjan municipal development indexes in 2016 pointed to a moderate development level for health and education (0.753 and 0.683, respectively) but low for employment and income (0.385). Access to energy is ample - 97% of households have electricity - while adequate sanitary supply and sewerage reach only 18% of the population (FIRJAN, 2018). The conditions represented by these indicators are part of the factors that measure how drought is felt and the impacts it causes.

Adaptation, as moderation of sensitivities and strengthening of adaptive capacities, modifies the conditions and, consequently, the impacts on communities. However, the measures adopted, as well as the potential adaptations, vary according to the reality of each social group. On the other hand, adaptive capacity depends on public policies appropriate to Brazil's social, economic, and environmental reality (RODRIGUES FILHO *et al.*, 2016).

In this sense, the following sections discuss in more detail specific vulnerabilities, adaptive measures, and opportunities for three different social groups: the traditional communities of Fundo de Pasto (FP) in northern Bahia, the Tuxá indigenous community in Rodelas/BA and the irrigated perimeters of the Juazeiro/BA-Petrolina/PE pole. These communities live in different socio-environmental situations, given the biophysical conditions of the regions where they are settled and because of specific historical processes to which they have been subjected. The Tuxá and the irrigated perimeters are on the banks of the São Francisco River, a location that gives them greater water access than pastureland communities, geographically distant from the perennial river channels. On the other hand, the indigenous community and the pastoralists are traditional groups based on centuries of traditions and informal norms that govern relations. The irrigated perimeters were only formed as a group after the formation of the irrigation districts in the 1970s. These contrasts between the three groups illustrate the plurality of contexts and specific issues within a region subject to the same climatic stress: drought.

The analysis of vulnerabilities and specific adaptations discussed below is based on secondary data, semi-structured interviews with community leaders and participatory workshops in the communities. The interviews were conducted in 2017 to map the consequences the drought that began in 2010 left on these populations' various aspects of life (Figure 1).

The workshops were held in 2018, aiming to consolidate and re-discuss the main impacts, threats, and opportunities for the future.

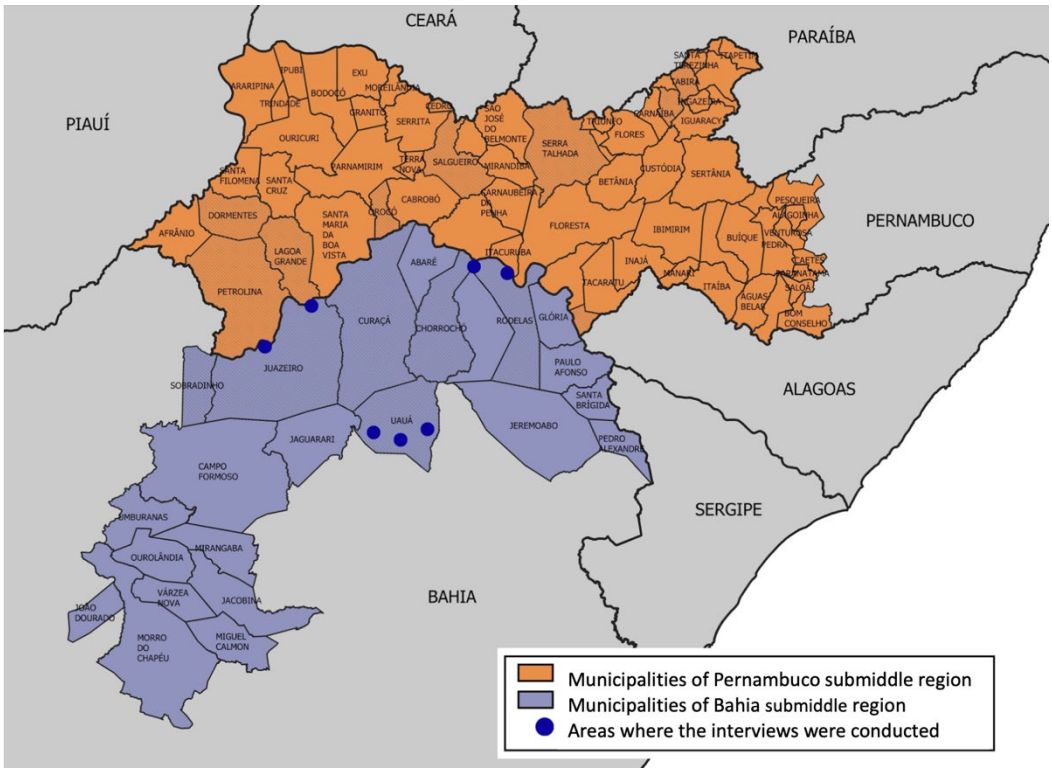

Figure 1 | Location of the interviewed communities in the Submédio da Bacia Hidrográfica do Rio São Francisco

Source: Prepared by the authors.

2 RESISTANCE AND COLLECTIVE PRODUCTION IN TRADITIONAL TERRITORIES OF SEMIARID BAHIA: THE CASE OF THE FUNDOS DE PASTO (COMMUNAL USE OF PASTURES)

The Fundos de Pasto (FP) are a social group that became territorialised in the semiarid region of the state of Bahia about two centuries ago, accumulating the values of traditional and peasant communities (MARQUES, 2016; SANTOS, 2011). The communities are identified by a "pattern of land occupation and use", associated above all with the communal use of land and pastures for grazing small animals (SANTOS, 2011). In general, the communities were formed based on family and crony ties and are an inheritance of the pattern of land occupation by *sesmarias* and unoccupied farms, dating from the 18th and 19th centuries, which partly became vacant lands (after the Land Law of 1850) (FERRARO, 2008).

The invisibility of the FPs throughout the 19th and early 20th centuries – because of low state interest in the territories they occupied - was, according to Ferraro (2008), fundamental to their consolidation as a social group. However, the advances in capital and water infrastructures brought changes resulting in the valorisation of the lands of the semiarid region of Bahia (SAB) and those occupied by the pastoralists. The FP conflicts with land grabbers - farmers - in the 1970s and 1980s, and the recognition of the FP by the state of Bahia at the end of the 1980s, boosted the formal organisation of these communities (SANTOS, 2011).

There were, in 2018, 373 Fundos e Fechos de Pasto communities formally identified by the state government of Bahia in 37 municipalities in Bahia, with Uauá being the municipality with the highest concentration of Fundos de Pasto (GEOGRAFAR, 2018). However, based on research surveys with social organisations, it is estimated that there are more than 500 communities, integrating 20,000 families distributed in 52 municipalities in Bahia in an area of over 1,200 hectares (FERRARO, 2008; REIS, 2015).

The main productive activity consists of raising goats and sheep, which graze in areas of the Caatinga biome. However, in a varied way, the communities practice agriculture aimed at self-consumption, the raising of other animals (such as chickens) and the extraction of native fruits of the biome, such as umbu (*Spondias tuberosa*) and passion fruit (*Passiflora cincinnata*) (REIS, 2015).

The nearly seven years of drought in the SAB, starting in 2010 (MARENGO *et al.*, 2018; SEYFFARTH; RODRIGUES, 2017), illustrate the impacts and resilience of FPs to climate stresses in the region. Rainfall shortages first affected food production for self-consumption. The decrease in this production - often cessation - impacts the family budget and quality of life by increasing food purchases, often with low nutritional quality.

The lack of rain not only compromises agricultural activity but also impacts the productivity and reproduction of the fauna and flora of the Caatinga itself. In this sense, agricultural and extractive activities are negatively affected. For some communities, extractivism is a complement to family income. Furthermore, the activity is synonymous with financial autonomy for many women. In the region of Uauá, Curaçá and Canudos, the Cooperative of Family Farming (Coopercuc) carries out the processing and marketing of fruit extracted from the Caatinga, mainly in the form of sweets and jams. Such production - with higher added value than the sale of the fruit *in natura* - was born from products made by women from the communities in their own homes. However, the prolonged drought has contributed, in recent years, to a significant decrease in extraction. The death of the umbuzeiro trees is one of the effects that most concern communities dedicated to extractivism in the region - a loss of about 40% of the species' tree population is reported (GAIVIZZO *et al.*, 2018).

Despite the impacts and the degree of water scarcity, the socioeconomic scenario in which the great drought from 2010 to 2017 allowed the maintenance of FP activities and livelihoods in the SAB (BUAINAIM; GARCIA, 2013; MARENGO *et al.*, 2018; SEYFFARTH; RODRIGUES, 2017). The public policies that have affected the region and the existing articulation between FP groups have provided the

population with adaptive capacities to deal with this climatic event. Two dimensions driven by public policies that have changed the communities' scenario in the recent past stand out: water security and food security.

Food security is associated with guaranteed income through institutional markets. In this sense, programmes for access to food and incentives for family farming - the Food Purchase Programme (PAA), the National School Meals Programme (Pnae) and social protection - the Bolsa Família Programme - have ensured, in recent years, income for food, production and other needs, including during droughts. The Bolsa Família contributes directly to the household budget by directly supplementing income constantly and stably. Thus, the cash transfer is especially relevant during periods of climatic stress - such as the last drought - because it is not sensitive to climate fluctuations. Institutional markets have indeed had a direct positive impact on production, as happened with the expansion of the cooperative Coopercuc, which has an increasing role in the income of communities in the region and, above all, in the economic empowerment of women, according to the narratives of FP leaders (ALMEIDA, 2018; GAIVIZZO *et al.*, 2018; LITRE *et al.*, 2018). The PAA and Pnae, therefore, enabled a greater flow of income from agro-extractive activities.

Water security - such as access to water for human consumption - has been transformed in recent decades by the implementation of cisterns for rainwater storage. In the view of the leaders interviewed, the expansion of this technology was one of the greatest recent transformations for local communities. Civil society organisations and, later, the 1 Million Cisterns Programme (P1MC) were responsible for the diffusion of the cistern for domestic use. The household cistern allows access to and storage of water next to the residence, dispelling the need to travel long distances to fetch small amounts of water for basic domestic activities. Given the last drought, the lack of rainfall to fill the cisterns was frequently reported. Even so, for the interviewees, having a form of storage close to their homes is fundamental for more continuous and secure access to water in emergency situations since it allows for storage when there is a tanker supply.

The role of mobilisation among communities in building water (SAITO, 2018) and food security, reiterated in the interviewees' statements, is worth highlighting. The FP associations are organised into Centrais and the Articulação Estadual, mobilised mainly around the purpose of land regularisation of the communities, which, in turn, integrate a broad network of territorial organisation, the Articulação para o Semiárido (ASA) (CARVALHO, 2014; SANTOS, 2011).

According to Gaivizzo *et al.* (2018), the territorial organisation of the FP is configured as an adaptive resource, as it allows and fosters the flow of knowledge. On the one hand, this organisation capacity is relevant for defending territorial rights - still in progress - necessary for the continuity of the communities. On the other, it transcends the land issue and promotes exchanges in technologies, experiences and learning in the direction of living with the Semi-Arid.

The scenario of coping with the latest drought in view of, among other factors, water and food security policies, contrasts with the past of the communities (BUAINAIM; GARCIA, 2013), which is still present in the memory of its members. However, it is possible to note the persistence of migration out of the communities. In the SSF, the intercensal survival ratio[5] (an index that points to emigration and/or mortality if below zero) of rural spaces was negative in 1980, 1991 and 2010 censuses – even if it went from 0.70 in 1980 to 0.81 in the last measurement - indicating a continuous rural exodus in the region. Migration out of the SSF towards other regions of the country increased in the same decades: the net migration rate[6] in 1980 was -2.5 compared to the sum of -3.5 in 2010 (ALMEIDA, 2018).

In the actors' view, however, migration has changed qualitatively. The interviewees described the exodus of the past as a survival-oriented measure. In this sense, entire families migrated, especially in periods of drought, due to a lack of alternatives. Distinctly, current migrations are led by young people and are not conditioned to the rains as they were in the past. Present-day migration is described

as a search for social mobility and is associated - by the elders - with a worrying devaluation of the traditional ways and customs of the communities (ALMEIDA, 2018).

The effects of drought on the FP reflect the possibilities of future adaptation, given that climate change may intensify extreme regional events (PBMC, 2013). For the case of the FP, the availability of water for production, environmental degradation and land tenure insecurity are highlighted. Social technologies to collect water for production are not yet as widespread as cisterns for consumption. However, the reports point to the complete abandonment of agricultural activities. Although less central, technologies that support productive backyards would potentially improve food and the household budget. The degradation of the Caatinga - both by direct anthropic action and lack of rainfall - means a growing threat to extractivism. In this sense, conservation measures for the Caatinga and the role of the FP in this process are relevant for future actions. Finally, access to and permanence on land is still uncertain among the FP, as many communities have not been recognised, and others face land-related pressures. Ensuring land tenure security is a starting point for further adaptive measures.

In this context, the results indicate that the design and access to public policies on food and water security, articulated with environmental conservation policies, among others, appropriate to the social contexts in the SAB is essential for the regulation of economic, migratory and sustaining dynamics of the productive activities of the FP over time, and thus, for coping with the climate impacts and risks projected for the region (PBMC, 2013).

3 THE DOUBLE EXPOSURE OF THE INDIGENOUS PEOPLES OF THE NORTH-EAST: THE TUXÁ OF RODELAS (BA) AND THEIR LONG STRUGGLE FOR LAND

The Tuxá indigenous people in Rodelas/BA, unlike the Fundos de Pasto communities, did not feel the immediate impact of the lack of rainfall due to their location on the banks of the Itaparica dam. However, the vulnerabilities of this community are conditioned to the reservoir itself, which some 30 years ago displaced them from their original territory. The lack of access to land - as well as its material and symbolic implications - represents, therefore, the main axis of insecurity, a threat intensified by the recent transfer of the prerogative of delimitation of indigenous lands to the Ministry of Agriculture, Livestock and Supply (BRAZIL, 2019) - which may embargo the recognition of the new territory demanded by the group.

O'Brien and Leichenko (2000) propose the concept of *double-exposure* to express the combined action of climate change and globalisation on populations, social groups and sectors that, over time, find themselves in a situation of heightened vulnerability. In the case of the Northeastern semiarid region and SSF, the impacts of globalisation have intensified since the modernising efforts conducted by the central government between the 1960s and 1980s, aimed at inserting the region into the emerging industrial dynamics and generating economic growth from this area. The dams in the São Francisco valley were one of the main vectors of this modernisation at the time, producing various local social and ecological impacts (ANDRADE, 1984), including the expropriation of the territory of the communities living around the river. According to Andrade (1984), the planning of the projects emphasised the technical and economic aspects of energy production without considering local aspects: agricultural areas, villages and towns were flooded. Added to the effects of this modernising process of the mid-20th century - which still have repercussions today - are the more recent dynamics of globalisation, notably land pressure for the implementation of new ventures, such as wind farms in the SSF. However, such initiatives have reinforced socio-environmental inequalities and vulnerabilities in the region (MILHORANCE *et al.*, 2019).

The Northeast is one of the Brazilian regions most subject to the adverse effects of climate change, leaving many populations unprotected (NOBRE; SAMPAIO; SALAZAR, 2008). However, indigenous peoples, in general, are among the most vulnerable populations: besides feeling these impacts,

they are affected by the adverse effects of globalisation, which strips them of their customs and induces them to paid work and processed food consumption. These groups have been experiencing economic and cultural difficulties due to the lack of demarcation of their territories. Due to the lack of space for the reproduction of their culture, and especially the production of subsistence food, they are at greater exposure.

According to the Socio-environmental Institute - ISA, land remains the main banner of the Brazilian Indians' claims. Although this right has been ratified by law in the Federal Constitution since 1988, many peoples continue to fight to recover their traditional territories (ISA, 2007). For indigenous peoples, besides being a natural resource and a means of subsistence, land adds other values and represents their physical and cultural survival. ISA states that in the Northeast, only 20% of indigenous territories are demarcated, in contrast to indigenous areas in the Amazon, where demarcation reaches over 90% of the lands.

According to the 2010 Census, there are 305 indigenous ethnic groups in Brazil which speak one or two of the 274 languages identified. In that year, these ethnic groups numbered 896,900 individuals, 36.2% in urban areas and 63.8% in rural areas. The Northeast contains 38 indigenous tribes, agglomerating 81 thousand people, which means 21% of the total indigenous population of Brazil (IBGE, 2012). Among these peoples are the Tuxá, who today, like several other peoples, await the demarcation of their territory lost after the construction of the Luiz Gonzaga Hydroelectric Power Plant (1985), causing the flooding of their main islands (Vieira *et al.*, 2015)[7]. According to members of the Tuxá community, in the past, the indigenous territory was made up of several river islands between Chorrochó (Barra do Tarrachil) and the Pajeú River, in the state of Bahia, an area of approximately 1,600 ha (VIEIRA *et al.*, 2015).

Today the Tuxá are divided and scattered into different groups in Bahia (in the municipalities of Rodelas and Ibotirama) and Pernambuco (Fazenda Funil). However, 30 years after losing their territory, they still await fair compensation or reparation from the São Francisco Hydroelectric Power Company (Chesf) and the State. They offered a restricted urban area for the resettlement of the community - in contrast to the vast area where they grew food - leaving a feeling of dissatisfaction, provoking a demand for the delimitation of an area suitable for the reproduction of their customs and food production.

Besides causing the division of the Tuxá, the forced displacement generated intense changes in the group's daily life, including loss of identity, migration, poverty and, in some families, food deficiency. According to members of the indigenous people, the work undertaken by Chesf led to the removal of their ancestors and territories, their ethnic and symbolic values, which were territorialised on their main island, Viúva. Weist (1995) states that people involuntarily removed due to the construction of development projects undergo mourning, cultural involution and restructuring of their lives due to the impact their culture suffers after losing the connection with the accustomed areas or territories where they used to move and organise themselves.

Given that culture is the result of a process of identity construction carried out by people and their surroundings, the landscape forms part of the construction of identity and culture, which support their representations. Duncan (1990) states that landscape is one of the determining factors enabling culture creation. However, Cosgrove (1998) indicates that the possession of land or territory is crucial since it represents the disposition and possession of a fortune, generating comfort, security and stability.

The territory is the intersection of time and space based on territorial memories and imaginaries. It forms part of a sign whose meaning is only understandable from the cultural codes in which it is inscribed. Unlike physical space, it has a cultural significance and social implications, where social practices are established with distinct interests, with different perceptions, valuations and territorial attitudes, which generate complementary and reciprocal relationships (GARCÍA, 1976; GOTTMANN, 1973). Space is an activity of the soul, in which social action and reciprocal action are inscribed as

the act of filling a space, forming associations through expressions. There is an important relationship between subjects and objects of a space, establishing not only the characteristics of concrete societies but also their temporal evolution (SIMMEL, 1926; 1979).

In this sense, the Tuxá people, after suffering the banishment, moved away from their daily life and altered their perception of happiness and wealth, experiencing the delimitation of their temporal evolution and the loss of history and tradition that the symbolic value of the territory offered them, in addition to their own practical capacity to produce what they consumed. For some community members, the distance from their land limited the interaction between them and their sacred, ancient and natural spaces, such as the waterfalls that used to exist, distancing them from their ceremonial centres and reducing the interaction with their ancestors and divinities.

The Tuxá people witnessed a socio-cultural breakdown due to the miscegenation of its members with the non-indigenous population of nearby towns, as well as the move away from ancestral practices of cultivation, hunting and fishing, leading them to take on expenses they did not previously have, of feeding their families. According to members of the indigenous population, the lost land allowed them to cultivate approximately 100 fertile hectares, where they produced rice, onions, fruit trees, vegetables, products that were added to the families' daily diet, as well as fish extracted from the São Francisco, or meat from domestic livestock. For many residents of Rodelas, those times are remembered as periods of abundance, peace and harmony, memories that evoke nostalgia and revolt.

Currently, according to data from FUNAI's Local Technical Coordination in Rodelas-BA, of the 490 families living in the town, more than 70% (424 families specifically) receive benefits from the Bolsa Família programme and a quarterly basic food basket subministered by the National Supply Company - Conab (FUNAI, 2018). This highlights the existence of families in poverty or extreme poverty by the low opportunities for income generation, partly due to the lack of territory for cultivation, which prevents them from improving their current diet and their economic situation, which could be strengthened through the production and marketing of agricultural products grown. Therefore, a longed-for delimitation of the Tuxá territory is observed in Rodelas, a situation which, according to them, would allow the reconstruction of part of their history and promote a return to those times when cultivation in the territory brought them abundance and allowed them to ensure good food, within the context of their food security.

4 IRRIGATED PERIMETER AND WATER AND FOOD SECURITY: REALITY AND PERSPECTIVES

The SSF lies entirely within the semiarid territory. This region has a long history of living with periods of drought, with low average annual precipitation associated with a high evapotranspiration rate (CBHSF, 2016). According to data from the Ministry of Environment (MMA, 2017), in terms of agricultural suitability, the Submédio has only 7% of its soil ~with good potential, with the remaining 93% classified as regular, restricted, unfavourable or inadvisable. More recently, the region was pointed out, along with other areas, as having a high degree of desertification (MMA, 2017).

Given the drought scenario, the reduction of water availability in the Basin in the semiarid region limits the use of water, whether for human and animal supply or the development of economic activities. Although there is no land more suitable for the development of irrigation agriculture throughout the Basin, agriculture and livestock is the one that uses the most water, with around 540 m3 of withdrawal flow for each R$ 1,000 of gross value added (GVA) (CBHSF, 2016). In the Submédio, the water demand for irrigation can exceed 10m3/s, as is the case of the sub-basins Curaçá [Curaçá 01] and Rio do Pontal [Pontal 01], which include the production hubs of Juazeiro-BA and Petrolina-PE (MMA, 2017).

Some public policies have been fostering the adoption of irrigation systems in the semiarid region, mainly in the last fifty years, as a promising practice for food production in the region, mitigating the impacts of irregular rainfall distribution on agricultural activities (CASTRO, 2018). Public Irrigation Projects (PPI or irrigated perimeters) are an example of such initiatives. The perimeters have a hydro-agricultural infrastructure, in parts of watersheds, with the demarcation of lots occupied by irrigating farmers (MACHADO *et al.*, 2017).

The irrigation perimeters were part of the Programme for the Development of Integrated Areas in the Northeast (Polonordeste), as part of a set of policies that aimed to form development poles in the less developed and less integrated areas of Brazil at the time (North and Northeast). The poles received infrastructure investments to receive activities of higher capital generation and promote a "conservative modernisation" of the local economy (ARAÚJO, 2000). In this sense, these places, including Juazeiro and Petrolina, became spots of higher income and more connected to the most dynamic economies of the country, as well as to external markets. The Polonordeste also had a collateral purpose of retaining the migratory flows that originated in the sertão towards the capitals and other regions. The development poles became intermediary centres that attracted emigrants from the region to their surroundings due to the economic dynamism of the pole (BURSZTYN, 2008).

In the case of the SSF, the irrigated perimeters are concentrated in the Juazeiro/Petrolina cluster, which is home to seven IPPs, all managed by the Companhia de Desenvolvimento dos Vales do São Francisco e Parnaíba (Codevasf). The first IPP was implemented in the region in 1968. Since then, a total area of over 114,000 hectares has been established. In these areas, the largest production is of fruit, mainly grapes and mango (SISPPI, 2018). The Juazeiro/Petrolina hub is considered an incentive for developing a large part of the production chain through the overlap of large agricultural and livestock production areas with the concentration of industries, promoting intensive modernisation in the region. The pole has the highest gross value added (GVA) growth of the primary sector in the SSF in the last decade, and a growth trend pointed out as very high (MMA, 2017).

However, the last cycle of drought in the region has generated many impacts on the activity, threatening its water and food security. The Rainfall Anomaly Index (CAI)[8] for the total annual precipitation for the municipality of Petrolina-PE in the period from 2010 to 2016 has remained negative (except for the year 2014, which had a timid positive value), with three years varying its intensity between very dry and extremely dry (SILVA *et al.*, 2017). Another important point to be analysed is the water availability of the Sobradinho reservoir upstream of the irrigated area. According to data from the National Water Agency[9], in November 2017, the volume of the Sobradinho reservoir reached less than 2% of its maximum level. If we consider the beginning of the dry period in 2010 (taking the Petrolina IAC as a reference), in November of that year, the useful volume of the Sobradinho reservoir closed the month at just over 33%.

The region's rainfall deficit and the consequent volume reduction is a climatic exposure factor that directly influenced the management of the Basin. Already in June 2017, the ANA released a resolution that established a measure to restrict the use of surface water withdrawal from the Basin, the so-called River Day, which took place on Wednesdays. The restriction even applied to water irrigation for perimeters irrigation (ANA, 2017). With a new resolution, in June 2018, withdrawals began to be suspended every fortnight, indicating an improvement in the hydrological conditions of the Basin (ANA, 2018).

Among the SSF social groups, family farmers in the Juazeiro/Petrolina irrigated area perceived the effects of the drought later. According to the farmers, the drought effects were noticed only after 2016, with more intensity after the 2017 use restrictions established by the ANA. However, even before this period, irrigators of some perimeters made some changes in the irrigation system of their properties. For example, farmers in the Mandacaru perimeter in Juazeiro use drip or micro-sprinklers to irrigate their crops. This change in irrigation method reduced approximately 50% of water and 30% of energy

use in the perimeter's properties as recently as 2013, according to Codevasf technicians (FEITOSA; MACHADO; FRANCO, 2017). In a way, the association of the infrastructure of the irrigation perimeters with the irrigation systems change contributed to improving water security for these farmers since their water availability had not been affected until that period.

Another impact perceived by farmers of the perimeter was the increased crop pests. They stated that, with the prolonged drought, pests do not find refuge in the dry Caatinga and begin affecting irrigated crops. With the increase in pests, these farmers use more pesticides to keep their crops productive. This increased use increases the total cost of production, which in most cases, cannot be passed on to consumers. Furthermore, the increased use of pesticides entails social and environmental consequences (e.g. soil and water contamination and health problems). In the case of water pollution, the problem is aggravated by scarcity itself, which means less capacity to dilute toxic substances.

On the other hand, most irrigation farmers do not have direct access to consumer markets but require the service of third parties who act as intermediaries in these transactions. The transfer of products to intermediaries further reduces the profitability of these farmers' production, reducing family income. To maintain food security, many farmers and their families need to supplement their income with other sources, usually outside the family farm enterprise. For Sabourin (2014), access to adequate markets is a problem faced by family farmers: "one of the difficulties of family farming forms lies in accessing partial and diversified markets adapted to their specific socioeconomic characteristics" (p. 21).

An alternative would be the creation of cooperatives as a form of social organisation to expand access to consumer markets or even strengthen associations of perimeter irrigators, the so-called irrigation districts. Currently, these associations are mainly responsible for the administration, operation, and maintenance of the irrigation infrastructure of common use. However, decisions on production and marketing are taken individually on each farm. In the case of the Mandacaru perimeter, a cooperative has already existed since the 1980s as a strategy of Codevasf. Although the company evaluated the results of the cooperative in the Mandacaru perimeter as satisfactory concerning the reduction of operating costs, the initiative was not successful, as were other cooperatives implemented by Codevasf in the irrigation districts. The main problems that may explain the failure of these cooperatives are associated mainly with the implementation process, cultural issues, and the lack of professional management of these enterprises (RIGO *et al.*, 2008).

The prospects for water security for irrigating communities are not encouraging. Trend scenarios point to a critical or very critical surface water balance for the SSF sub-basins in 2025 and 2035, showing a clear mismatch between demand and availability. In the case of agriculture and livestock, even adding a factor to analyse the ability to meet water needs, the Juazeiro/Petrolina hub still shows a tendency towards a very critical surface water balance in the two years considered (CBHSF, 2016). In this sense, it is a challenge to associate the perspectives of water availability with new alternatives for intelligent water use in agricultural production. However, other factors that promote the adaptive capacity of these social-ecological systems deserve to be considered (such as access to markets adapted to their particularities) in the promotion of water and food security of farming families in the irrigated perimeter.

5 FINAL CONSIDERATIONS

The analysis of different vulnerable groups shows that adaptation - as moderation of sensitivities and strengthening of adaptive capacities - varies according to the specific vulnerabilities of the multiple and contrasting realities that coexist in the SSS. From a systemic vision, one can understand the potential and future possibilities for the region, defined as the properties of social and natural systems that favour adaptation to climatic stresses. The cases presented illustrate that adaptation is conditioned to the physical characteristics of the place where the population is located (such as the rainfall regime

and proximity to perennial water bodies, factors that condition the "risk"). However, it also depends on various social, economic, cultural and political factors.

Beyond the specificities of each population, it is necessary to consider the interconnectedness of sectors, scales and actors, as well as integrated approaches that minimise trade-offs and maximise synergies between sectoral policy responses. The interdependence of society and the environment reflects the importance of integrated analyses and actions that relate physical, biological, social, political and economic aspects in the search for strategies that promote the resilience of such systems. This interdependence is well represented, on the one hand, by ecosystem services (the benefits to people produced and delivered by naturally functioning ecosystems, their characteristics, functions, or ecological processes), which are the pillars that sustain humanity and its activities (COSTANZA *et al.*, 2017; CUMMING *et al.*, 2017; MILLENIUM ECOSYSTEM ASSESSMENT, 2005).

On the other hand, the interconnection of society with the environment is also exemplified through policies regulating access to and use of such services. The Nexus approach - which explores the connections between water, energy, and food - appears as a proposal to promote adaptations and resilience in an integrated manner. The groups studied point to the relevance of addressing overlaps and connections in adaptations. In other words, actions for the region should address not only the specificities but the relationship between them and the systemic panorama of the region.

The lack of rainfall and water scarcity highlight the various uses of water and, above all, the conflicts and potentialities that emerge between sectors and groups. Water in the region is used to supply urban centres through dams and reservoirs; for human consumption and food production in family agriculture through reservoirs, wells, water tankers and social collection technologies; the dammed water that serves these publics also serves to irrigate irrigated agriculture plots (both corporate and family) and is used to produce energy distributed in the region and beyond. In this sense, as Nexus postulates, water is a resource that connects a diversity of actors and interests within the region and evokes the need for policies and analytical approaches that understand them in a connected way.

The three groups worked on here demonstrate the plurality of impacts occurring within a region with the same historical background and under the same climatic stress. However, we can observe that the apparently specific vulnerabilities cannot be understood in isolation. The water for energy production dammed in Sobradinho Lake is the same water required to irrigate the agricultural perimeters of Juazeiro and Petrolina. Electricity generation generates conflicts of interest of a different nature 300 km downstream, where the Tuxá are still trying to recover their productive and cultural dynamics 30 years after the flooding of the Itaparica lake. 120 km away, the challenges of rural activity in Juazeiro/Petrolina and in Uauá illustrate the contrasts inherited by public action (or omission) in the region's past: the food and income security of the Fundo de Pasto communities are still subject to rainfall variation and uncertainties regarding land regulation, as opposed to the public irrigated perimeters, which have not felt the effects of six years of drought so intensely but lack the mobilisation capacity of traditional communities.

As such, climate adaptation and, more broadly, the sustainable development of regions such as the one exemplified by the studies carried out in the SSF depend on understanding their heterogeneity and complexity and connections established within the sub-basin and beyond.

NOTES

1| Agenda 2030. Available at: https://nacoesunidas.org/pos2015/agenda2030/.

2| National Policy on Climate Change (PNMC), Law 12.187, 2009. Available at: http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2009/lei/l12187.htm.

3| National Adaptation Plan (NAP). Available at: http://www.mma.gov.br/clima/adaptacao/plano-nacional-de-adaptacao.

4| The IAC is a method to assess climate change at local level based on the behaviour of the rainfall regime (SILVA *et al.*, 2017). The IAC analyses the frequency and intensity of dry and rainy years. If it is positive (positive anomaly), it indicates that the observed values are above the historical average of precipitation in the region. If it is negative (negative anomaly), it indicates that the rainfall volume was lower than the historical average (SOBRAL *et al.*, 2018).

5| The Intercensal Survival Ratio (ISSR) provides an indication of the out-migration of young people from rural areas in the submontane region. The RIS is the difference of a population cut-off between a Demographic Census and the previous census. In this sense, it reflects the decrease (values less than 1) or increase (values greater than 1) in the population of a given age group. In cases of negative RIS, the value can indicate three different phenomena: i) emigration, ii) mortality and iii) changes in the definition of rural and urban spaces between the censuses (MAIA; BUAINAIN, 2015).

6| Difference between immigrant and emigrant population, over total population of region, multiplied by 100.

7| The Luiz Gonzaga Hydroelectric Power Plant (formerly known as Itaparica Hydroelectric Power Plant) is located in the Brazilian states of Bahia and Pernambuco. It belongs to the Chesf company and was renamed in honour of the Brazilian singer-songwriter Luiz Gonzaga do Nascimento (1912-1989).

8| Method for assessing climate change at local level based on the behaviour of the rainfall regime (SILVA *et al.*, 2017).

9| Data from the Reservoir Monitoring System/SAR. Available at: http://sar.ana.gov.br/MedicaoSin. Accessed: dec. 2018.

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Políticas públicas e adaptação às mudanças climáticas: três estudos de casos no semiárido brasileiro

Public Policies and Adaptation to Climate Change: Three Case Studies in the Brazilian Semi-Arid Region

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ARTICLE- VARIA

RESUMO

A adaptação às mudanças climáticas, entendida como moderação das sensibilidades e fortalecimento das capacidades adaptativas, modifica as condições e consequentemente os impactos do clima nas populações vulneráveis. Por outro lado, a capacidade adaptativa depende de políticas públicas adequadas à realidade social, econômica e ambiental. Nesse contexto, o presente artigo discute vulnerabilidades específicas, medidas adaptativas e oportunidades identificadas por meio de entrevistas semiestruturadas e oficinas participativas em três grupos de diferentes perfis socioambientais: as comunidades tradicionais de Fundo de Pasto (FP) no norte da Bahia, a comunidade indígena Tuxá em Rodelas/BA e os perímetros irrigados do polo Juazeiro/BA-Petrolina/PE. Os estudos de caso confirmam que a adaptação está fortemente condicionada às características físicas do local em que a população se encontra (como o regime de chuvas e proximidade de corpos hídricos perenes, fatores que condicionam o "risco"); mas que também depende de uma ampla gama de fatores sociais, econômicos, culturais e políticos.

Palavras-chave: Adaptação. Mudanças climáticas. Políticas públicas. Semiárido. Brasil.

ABSTRACT

Adaptation to climate change, understood as the moderation of sensitivities and the strengthening of adaptive capacities modifies the conditions and, consequently, the impacts of climate change on vulnerable populations. On the other hand, adaptive capacity depends on public policies tailored to different groups' social, economic, and environmental realities. This article discusses specific vulnerabilities, adaptive measures and opportunities identified through semi-structured interviews and participatory workshops in three groups with different socio-environmental profiles: the Fundo de Pasto (FP) traditional communities in Northern Bahia, the Tuxá indigenous community in Rodelas/BA and the irrigated perimeters of the Juazeiro/BA-Petrolina/PE pole. These case studies confirm that adaptation is strongly conditioned by the physical characteristics of the region where the population is located (such as rainfall levels and proximity to perennial water bodies, which condition "risks"); but that it also depends on a wide range of social, economic, cultural, and political factors.

Keywords: *Adaptation. Climate change. Public policies. Semiarid region. Brazil.*

1 INTRODUÇÃO

A mudança climática emerge como um dos principais desafios para a governança ambiental global no século XXI, além de impor uma série de riscos para a manutenção dos sistemas socioeconômicos em escala global. Esses riscos vêm sendo enfrentados em duas frentes. A primeira, chamada *mitigação*, atua sobre as causas da mudança do clima por meio do controle das concentrações dos gases de efeito estufa. A segunda, denominada *adaptação*, reúne os esforços para amenizar os impactos inevitáveis da mudança do clima e gerir as vulnerabilidades climáticas, presentes e futuras.

Inicialmente tratada como tema à parte na agenda política, a partir da década de 2000 a adaptação à mudança climática emerge como tema transversal do desenvolvimento sustentável (DS) (ADGER *et al.*, 2009; LAHSEN *et al.*, 2010). Mais recentemente, foi incorporada pela ONU entre os Objetivos do Desenvolvimento Sustentável – ODS[1]. No Brasil, a adaptação foi institucionalizada na Política Nacional sobre Mudança do Clima – PNMC[2] e, em 2016, foi criado um plano governamental específico para tratar o tema, o Plano Nacional de Adaptação[3], tendo por objetivo a sua consideração pelas agendas setoriais. A internalização crescente da adaptação no processo político vem demandando da comunidade científica arcabouços teóricos e analíticos capazes de fornecer conceitos e métodos de análise operacionais que dialoguem com a tomada de decisão. Nesse sentido, diferentes marcos foram propostos, dos quais destaca-se o arcabouço da *vulnerabilidade*, empregado pelo Painel Intergovernamental sobre Mudanças Climáticas – IPCC, e o da *resiliência*.

A abordagem da vulnerabilidade, originada da Geografia, possui diferentes propostas de marcos teórico-conceituais, mas os que adquiriram maior popularidade foram aqueles sintetizados pelo IPCC. Em seu relatório AR5, de 2014, o IPCC trouxe um arcabouço da vulnerabilidade ligeiramente distinto dos que vinha adotando até então (OPPENHEIMER *et al.*, 2014). Nele, vulnerabilidade é entendida como predisposição ou propensão de um sistema em ser afetado de forma adversa por um *hazard* (perigo). *Hazard* se refere ao evento físico, natural ou induzido pelos humanos, com potencial de causar perdas e danos em ecossistemas e em sistemas humanos, assim como nos serviços ambientais dos quais estes dependem. Outro conceito importante é o de *exposição*, empregado para descrever a presença dos sistemas socioecológicos em formatos e áreas que podem ser afetadas de forma adversa (OPPENHEIMER *et al.*, 2014).

A vulnerabilidade é determinada pela confluência de diferentes fatores socioeconômicos, ambientais e institucionais, sintetizados em dois conceitos pelo IPCC: *sensibilidade* e *capacidade adaptativa*. O primeiro se refere a características internas dos sistemas com as quais o *hazard* interage na determinação da magnitude do efeito adverso (LINDOSO, 2017). Já o segundo, diz respeito à capacidade dos sistemas, instituições, pessoas e outros organismos em se ajustar a potenciais efeitos adversos, aproveitar oportunidades ou responder a impactos concretos do clima (IPCC, 2014). A partir do AR5, a abordagem de risco ganhou grande relevância no IPCC, cujo conceito é entendido como função da exposição, vulnerabilidade e probabilidade de ocorrência do *hazard*, funcionando, portanto, como o elemento organizador do arcabouço conceitual e analítico (OPPENHEIMER *et al.*, 2014).

Apesar do foco do AR5 no *hazard*, há na literatura em vulnerabilidade socioambiental abordagens que conferem maior ênfase aos fatores sociais, econômicos, políticos e histórico-estruturais como fontes de pressão sobre certos setores populacionais (GALLOPÍN, 2006; VALENCIA, 2016). Tais abordagens não empregam a vulnerabilidade como a consequência linear da incidência de um risco físico (o *hazard*) sobre um grupo, mas a compreendem como um processo circular e multidimensional (O'BRIEN *et al.*, 2007). Nesse sentido, fatores institucionais, socioeconômicos e biofísicos conformam as condições contextuais que determinam a vulnerabilidade. Essas condições, por sua vez, afetam e são afetadas não apenas pelos riscos e eventos físicos, mas pelas estruturas e mudanças sociais, econômicas e políticas.

O arcabouço da resiliência, por sua vez, tem raízes na Ecologia. É um conceito que vem sendo empregado na literatura sobre mudança climática para descrever a capacidade dos sistemas socioecológicos em sofrer distúrbios e ainda assim manter sua estrutura, funções e identidade básicas por meio do aprendizado, reorganização e desenvolvimento (IPCC, 2014; NORBERG; CUMMING, 2008). É frequentemente usada como sinônimo de capacidade adaptativa na literatura da mudança do clima (LINDOSO, 2017).

Na abordagem da vulnerabilidade, adaptação climática é entendida como moderação de sensibilidades, redução da exposição e fortalecimento de capacidades adaptativas. Essa abordagem concentra-se em compreender contextos que condicionam a vulnerabilidade de sistemas socioecológicos (LINDOSO, 2017). Na abordagem da resiliência, adaptação é empregada para descrever construção de resiliência. O foco dessa abordagem é entender os processos de resposta desses sistemas (LINDOSO, 2017). Em um contexto no qual uma diversidade de fatores, inclusive estruturais, limitam a capacidade dos sistemas socioecológicos de se adaptarem, os processos de resposta – como o aprendizado, a reorganização e o desenvolvimento – são tão relevantes quanto o contexto que determina a resposta.

Há, portanto, uma convergência dos dois arcabouços teórico-conceituais. Nesse contexto, a perspectiva dos sistemas socioecológicos é um espaço epistêmico favorável ao encontro interdisciplinar (BINDER *et al.*, 2013). Ela é cara tanto à abordagem da resiliência quanto à da vulnerabilidade, e tem sua relevância analítica no reconhecimento de que as dinâmicas dos sistemas humanos e naturais estabelecem relações indissociáveis (GALLOPÍN, 2006; TURNER *et al.*, 2003). Separá-las em análises isoladas pode produzir resultados equivocados.

Esse mesmo entendimento é compartilhado pela abordagem Nexus, que vem ganhando grande proeminência na agenda política dos ODS e possui grande interface com os esforços de adaptação à (e mitigação) mudança do clima (LINDOSO *et al.*, 2018; RASUL; SHARMA, 2015). A abordagem Nexus adota principalmente, mas não exclusivamente, a perspectiva de três seguranças: hídrica, alimentar e energética, tomadas sempre em conjunto. A inovação da abordagem está nas relações de *trade-offs* e sinergias entre os silos, dando, portanto, grande ênfase às dimensões político-institucionais e normativas (KURIAN, 2017). Os críticos do Nexus desconfiam da capacidade da abordagem de ser operativa, pois ainda carece de consensos conceituais e metodológicos (GALAITSI *et al.*, 2018), enquanto seus defensores argumentam que essa flexibilidade é justamente o que torna a abordagem interessante dentro de um contexto científico e político fundamentado em diferentes áreas do conhecimento e agendas (BROUWER *et al.*, 2018).

Uma região que tem merecido atenção pela complexidade e possibilidade de maior evidenciação do componente de segurança hídrica articulado aos demais é a Bacia Hidrográfica do Rio São Francisco, especialmente em seu trecho Submédio – SSF. O principal risco (*hazard*) a que a região está sujeita é a variabilidade das chuvas. O SSF está inserido no semiárido brasileiro, que enfrenta um clima seco e de baixa precipitação, e tem como um importante vetor de exposição as secas prolongadas. Recentemente, a região foi exposta a um dos mais intensos períodos de seca. No SSF, em 2010, houve uma forte redução do Índice de Anomalia de Chuva (IAC[4]), sendo que entre 2012 e 2016, o IAC manteve-se negativo, na maioria dos anos abaixo de -2, indicando um clima muito ou extremamente seco (SOBRAL *et al.*, 2018). Apesar disso, o Rio São Francisco, que atravessa a área, possibilita a existência de diferentes dinâmicas em relação à disponibilidade e ao acesso à água.

Além disso, os distintos grupos e subespaços do SSF possuem, por um lado, fatores de vulnerabilidade contextual em comum por pertencerem à mesma região com traços físicos, culturais e históricos específicos. Ao mesmo tempo, há muitas diferenças nos contextos de vulnerabilidade desses grupos, na medida em que processos sociais, econômicos e políticos e mesmo a localização geográfica delinearam contrastes entre eles. Sobretudo a partir das políticas de desenvolvimento e modernização das décadas de 1960 a 1980, o SSF modificou-se e tornou-se mais heterogêneo. A formação dos

perímetros públicos de agricultura irrigada e o polo de agroindústria de Petrolina e Juazeiro, bem como os empreendimentos energéticos no Rio São Francisco, deram origem a novos subgrupos beneficiados pelos projetos, novas desigualdades e alteraram as dinâmicas da região (ANDRADE, 1984; ARAÚJO, 2000; BURSZTYN, 2008; SCOTT, 2009).

As sensibilidades e capacidades adaptativas das comunidades que vivem no SSF são, portanto, bem diferentes e dizem respeito a diversas dimensões, como, por exemplo, terra, água, alimento, trabalho, renda, saúde, migração e mobilidade, e variam de acordo com a condição de cada grupo social. No entanto, alguns indicadores podem prover uma perspectiva das condições socioeconômicas gerais, sob as quais a população do Submédio foi exposta ao recente período de seca. Os índices Firjan de desenvolvimento municipal, em 2016, apontaram para um nível de desenvolvimento moderado para saúde e educação (0,753 e 0,683, respectivamente), no entanto, baixo para o quesito emprego e renda (0,385). O acesso à energia é amplo – 97% dos domicílios possuem energia elétrica – já o abastecimento e esgotamento sanitário adequados atingem apenas 18% da população (FIRJAN, 2018). As condições representadas por esses indicadores fazem parte do conjunto de fatores que mediam a forma como a seca é sentida e condicionam os impactos que provoca.

A adaptação, como moderação das sensibilidades e fortalecimento das capacidades adaptativas, modifica as condições e consequentemente os impactos nas comunidades. No entanto, as medidas adotadas, bem como as adaptações potenciais, variam de acordo com a realidade de cada grupo social. Por outro lado, a capacidade adaptativa depende de políticas públicas adequadas à realidade social, econômica e ambiental no Brasil (RODRIGUES FILHO *et al*., 2016).

Nesse sentido, as próximas seções discutem em mais detalhes vulnerabilidades específicas, medidas adaptativas e oportunidades para grupos sociais de diferentes perfis: as comunidades tradicionais de Fundo de Pasto (FP) no norte da Bahia, a comunidade indígena Tuxá, em Rodelas/BA, e os perímetros irrigados do polo Juazeiro/BA-Petrolina/PE. Essas comunidades encontram-se em situações socioambientais distintas, tanto pelas condições biofísicas dos locais em que estão inseridas quanto por processos de formação específicos a que estiveram sujeitas. Os Tuxá e os perímetros irrigados estão às margens do Rio São Francisco, localização que lhes confere maior acesso a água do que as comunidades de Fundo de Pasto, geograficamente distantes da calha de rios perenes. Por outro lado, a comunidade indígena e os Fundos de Pasto são grupos tradicionais, calcados em séculos de tradições e normas informais que regem as relações, enquanto os perímetros irrigados apenas constituíram-se enquanto grupo a partir da formação dos distritos de irrigação da década de 1970. Esses contrastes entre os três grupos ilustram a pluralidade de contextos e questões específicas que podem existir dentro de uma região sujeita ao mesmo estresse climático: a seca.

A análise das vulnerabilidades e adaptações específicas discutidas a seguir tem como base dados secundários, entrevistas semiestruturadas a lideranças comunitárias e oficinas participativas nas comunidades. As entrevistas foram realizadas em 2017, com o objetivo de mapear as consequências da seca iniciada em 2010 sobre diversos aspectos da vida dessas populações (Figura 1). As oficinas foram realizadas em 2018, visando consolidar e re-discutir os principais impactos, bem como as ameaças e oportunidades para o futuro.

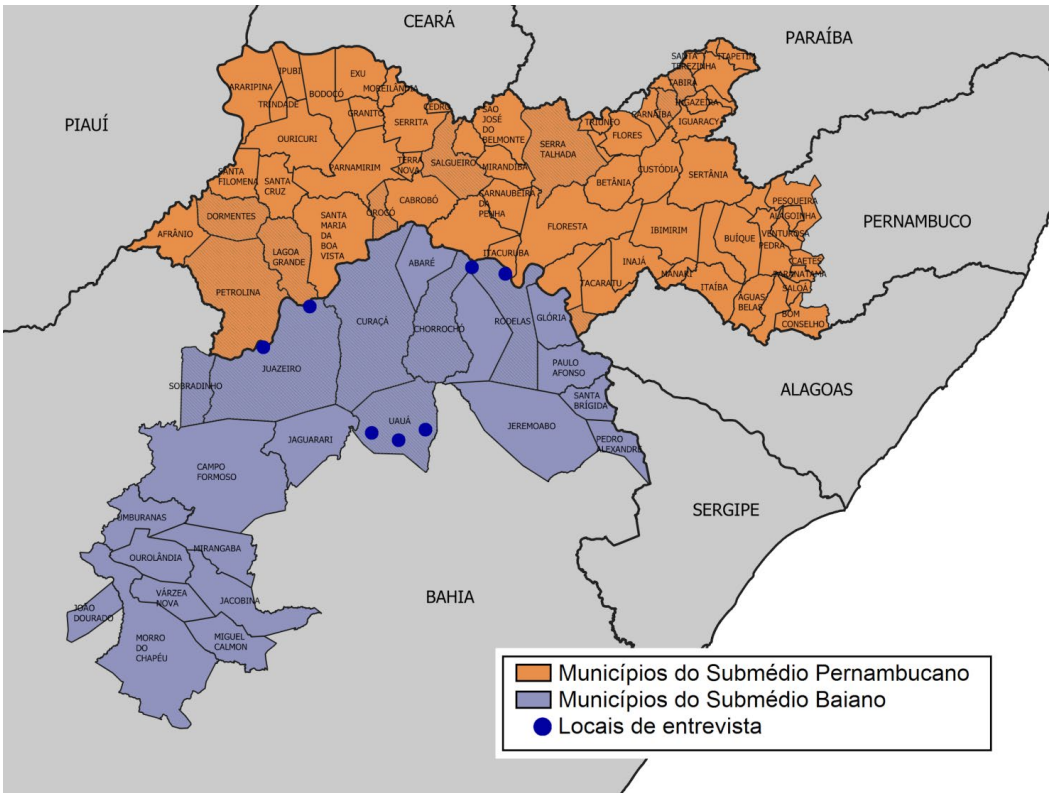

Figura 1 | Localização das comunidades entrevistadas no Submédio da Bacia Hidrográfica do Rio São Francisco

Fonte: Elaboração própria.

2 RESISTÊNCIA E PRODUÇÃO COLETIVA EM TERRITÓRIOS TRADICIONAIS DO SEMIÁRIDO BAIANO: O CASO DOS FUNDOS DE PASTO

Os Fundos de Pasto (FP) são um grupo social que se territorializou na região semiárida do estado da Bahia há cerca de dois séculos, acumulando valores de comunidades tradicionais e camponesas (MARQUES, 2016; SANTOS, 2011). As comunidades se identificam por um "padrão de ocupação e uso da terra", associado sobretudo ao uso comunal da terra para o pastoreio de animais de pequeno porte (SANTOS, 2011). Em geral, as comunidades se formaram a partir de vínculos familiares e de compadrio, e são uma herança do padrão de ocupação de terras por sesmarias e de fazendas desocupadas, datadas dos séculos XVIII e XIX, que em parte se tornaram terras devolutas – a partir da Lei de Terras de 1850 (FERRARO, 2008).

A invisibilidade dos FP ao longo do século XIX e início do século XX – em função do baixo interesse estatal pelos territórios que ocupavam – foi, segundo Ferraro (2008), fundamental para a sua consolidação como grupo social. Entretanto, os avanços do capital na região e a construção das obras de infraestrutura hídrica trouxeram mudanças que resultaram na valorização das terras do semiárido baiano (SAB) e, consequentemente, das terras ocupadas pelos FP. Os conflitos dos FP com "grileiros" de terra – fazendeiros nas décadas de 1970 e 1980 e o reconhecimento dos FP pelo estado da Bahia, no final dos anos 1980, impulsionaram a organização formal dessas comunidades (SANTOS, 2011).

Havia, em 2018, 373 comunidades de Fundos e Fechos de Pasto formalmente identificadas pelo governo do estado da Bahia em 37 municípios baianos, sendo Uauá o município com maior concentração de Fundos de Pasto (GEOGRAFAR, 2018). Contudo, com base em levantamentos de pesquisa com organizações sociais, estima-se que existam mais de 500 comunidades, que integram 20 mil famílias distribuídas em 52 municípios baianos numa área superior a 1,2 mil hectares (FERRARO, 2008; REIS, 2015).

A principal atividade produtiva consiste na criação de caprinos e ovinos, que pastam em áreas do bioma Caatinga. No entanto, de forma variada, as comunidades praticam a agricultura voltada ao autoconsumo, a criação de outros animais (como galinhas) e o extrativismo de frutas nativas do bioma, a exemplo do umbu (*Spondias tuberosa)* e do maracujá da caatinga (*Passiflora cincinnata)* (REIS, 2015).

Os quase sete anos de seca no SAB, iniciada em 2010 (MARENGO *et al*., 2018; SEYFFARTH; RODRIGUES, 2017), ilustram os impactos e também a resiliência dos FP aos estresses climáticos na região. A escassez de chuva, primeiramente, afetou a produção de alimentos para o autoconsumo. A diminuição dessa produção – frequentemente a cessação – impacta o orçamento familiar e a qualidade de vida ao aumentar a compra de alimentos, frequentemente, com baixa qualidade nutricional.

A escassez de chuva não apenas compromete a atividade agrícola, mas também impacta a produtividade e a reprodução da fauna e flora da própria Caatinga. Nesse sentido, as atividades agropastoris e extrativistas são negativamente afetadas. Para algumas comunidades, o extrativismo é um complemento de renda familiar. Ademais, a atividade é sinônimo de autonomia financeira para muitas mulheres. Na região de Uauá, Curaçá e Canudos, a Cooperativa Agropecuária Familiar (Coopercuc) realiza o beneficiamento e a comercialização de frutos extraídos da Caatinga, principalmente na forma de doces e compotas. Tal produção – de maior valor agregado do que a venda do fruto *in natura* – nasceu de produtos feitos por mulheres das comunidades em suas próprias casas. No entanto, a seca prolongada contribuiu, nos últimos anos, para uma sensível diminuição na extração. A morte dos umbuzeiros é um dos efeitos que mais preocupam comunidades dedicadas ao extrativismo na região – relata-se uma perda de cerca de 40% da população de árvores da espécie (GAIVIZZO *et al*., 2018).

Apesar dos impactos e do grau de escassez hídrica, o cenário socioeconômico no qual ocorreu a grande seca de 2010 a 2017 permitiu a manutenção das atividades e meios de vida dos FP no SAB (BUAINAIM; GARCIA, 2013; MARENGO *et al*., 2018; SEYFFARTH; RODRIGUES, 2017). As políticas públicas que incidiram sobre a região, bem como a articulação existente entre os grupos de FP, proveram à população capacidades adaptativas para lidar com esse evento climático. Destaca-se, nessa seara, duas dimensões que – impulsionadas por políticas públicas – alteraram o cenário das comunidades no passado recente: segurança hídrica e segurança alimentar.

A segurança alimentar está associada à garantia da renda por meio dos mercados institucionais. Nesse sentido, programas de acesso à alimentação e incentivo à agricultura familiar –o Programa de Aquisição de Alimentos (PAA), o Programa Nacional de Alimentação Escolar (Pnae) e de proteção social – o Programa Bolsa Família – asseguraram, nos últimos anos, renda para alimentação, produção e outras necessidades, inclusive durante a seca. O Bolsa Família contribui de forma direta no orçamento doméstico, ao complementar diretamente a renda de forma constante e estável. Dessa forma, a transferência de renda é especialmente relevante durante os períodos de estresse climático – como a última seca – por não ser sensível às oscilações do clima. É verdade que os mercados institucionais tiveram um impacto positivo direto sobre a produção, como aconteceu com a expansão da Coopercuc, que tem papel crescente na renda das comunidades da região e, sobretudo, no empoderamento econômico das mulheres, conforme as narrativas de lideranças dos FP (ALMEIDA, 2018; GAIVIZZO *et al*., 2018; LITRE *et al*., 2018). O PAA e o Pnae, portanto, possibilitaram um maior fluxo de renda advindo da atividade agroextrativista.

A segurança hídrica – como o acesso a água para o consumo humano – transformou-se nas últimas décadas pela implementação de cisternas para armazenamento da água das chuvas. Na visão das lideranças entrevistadas, a expansão dessa tecnologia foi uma das maiores transformações recentes para as comunidades locais. Organizações da sociedade civil e, posteriormente, o Programa 1 Milhão de Cisternas (P1MC) foram responsáveis pela difusão da cisterna de consumo (armazenamento de água da chuva para uso doméstico). A cisterna de consumo doméstico permite o acesso e armazenamento de água ao lado da residência, dissipando a necessidade de percorrer longas distâncias para buscar pequenas quantidades de água para atividades domésticas básicas. Diante da última seca, foi

frequentemente relatada a insuficiência das chuvas para encher as cisternas. Ainda assim, para os entrevistados, possuir uma forma de armazenamento próximo a residências é fundamental para o acesso mais contínuo e seguro à água em situações emergenciais, já que permite a estocagem quando há fornecimento por caminhão-tanque.

Vale ressaltar o papel da mobilização entre as comunidades na construção da segurança hídrica (SAITO, 2018) e alimentar, reiterada nos depoimentos dos entrevistados. As associações de FP estão organizadas em Centrais e na Articulação Estadual, mobilizadas sobretudo em torno do propósito de regularização fundiária das comunidades, que, por sua vez, integram uma ampla rede de organização territorial, a Articulação para o Semiárido (ASA) (CARVALHO, 2014; SANTOS, 2011).

A organização territorial dos FP se configura, segundo GAIVIZZO *et al*. (2018), como um recurso adaptativo, na medida em que permite e fomenta o fluxo de conhecimento. Por um lado, essa capacidade de organização é relevante para a defesa dos direitos territoriais – ainda em andamento – necessários para a continuidade das comunidades. Por outro, transcende a questão fundiária e promove trocas sobre tecnologias, experiências e aprendizagem em direção à convivência com o semiárido.

O cenário de enfrentamento da última seca, tendo em vista, entre outros fatores, as políticas de segurança hídrica e alimentar, contrasta com o passado das comunidades (BUAINAIM; GARCIA, 2013), ainda presente na memória de seus membros. Contudo, é possível notar a persistência da migração para fora das comunidades. No SSF, a razão intercensitária de sobrevivência[5] (índice que, abaixo de zero, aponta para a emigração e/ou mortalidade) dos espaços rurais foi negativa nos censos de 1980, 1991 e 2010 – apesar de ter subido de 0,70 em 1980 para 0,81 na última medição – indicando a continuidade do êxodo rural na região. A migração para fora do SSF, em direção a outras regiões do país, aumentou nas mesmas décadas: a taxa líquida de migração[6] em 1980 foi -2,5 comparada à soma de -3,5 em 2010 (ALMEIDA, 2018).

Na visão dos atores, no entanto, as migrações mudaram qualitativamente. Os entrevistados descreviam o êxodo do passado como uma medida orientada à sobrevivência. Nesse sentido, famílias inteiras migravam, sobretudo em períodos de seca, diante da falta de alternativas. Distintamente, as migrações atuais são protagonizadas pelos jovens, e não estão condicionadas às chuvas como estiveram no passado. A migração do presente é descrita como uma busca por mobilidade social e associada – pelos mais velhos – a uma preocupante desvalorização dos modos e costumes tradicionais das comunidades (ALMEIDA, 2018).

Os efeitos da seca para os FP trazem reflexões acerca das possibilidades de adaptação futuras, tendo em vista que as mudanças climáticas podem intensificar os eventos extremos na região (PBMC, 2013). Pontua-se, para o caso dos FP, a disponibilidade de água para a produção, a degradação ambiental e a insegurança fundiária. Tecnologias sociais de captação de água para a produção ainda não são tão difundidas quanto as cisternas de consumo. No entanto, os relatos apontaram o completo abandono das atividades agrícolas. Embora menos centrais, tecnologias que suportem quintais produtivos potencialmente melhorariam a alimentação e o orçamento doméstico. A degradação da Caatinga – tanto pela ação antrópica direta quanto pela falta de chuvas – significa uma crescente ameaça ao extrativismo. Nesse sentido, medidas de conservação da Caatinga e o papel dos FP nesse processo são um ponto relevante para as ações futuras. Por fim, o acesso e permanência na terra ainda é uma incerteza entre os FP na medida em que muitas comunidades não foram reconhecidas e outras enfrentam pressões fundiárias. A garantia da segurança fundiária figura, portanto, como um ponto de partida para outras medidas adaptativas.

Nesse contexto, os resultados apontam que o desenho e o acesso às políticas públicas de segurança alimentar e hídrica, articulados com políticas de conservação ambiental, entre outras, adequadas aos contextos sociais no SAB, são essenciais para a regulação das dinâmicas econômicas, migratórias e

de sustentação das atividades produtivas dos FP ao longo do tempo, e, assim, de enfrentamento dos impactos e riscos climáticos projetados para a região (PBMC, 2013).

3 A DUPLA EXPOSIÇÃO DOS POVOS INDÍGENAS DO NORDESTE: OS TUXÁ, DE RODELAS (BA), E SUA LONGA LUTA POR TERRA

Os indígenas Tuxá, em Rodelas/BA, diferentemente das comunidades de Fundos de Pasto, não sentiram impactos tão imediatos da falta de chuvas, por conta de sua localização às margens da represa de Itaparica. No entanto, as vulnerabilidades dessa comunidade estão condicionadas ao próprio reservatório, que há cerca de 30 anos os desalojou de seu território original. A falta de acesso à terra, bem como suas implicações materiais e simbólicas, representa, portanto, o eixo principal de insegurança, ameaça intensificada pela recente transferência da prerrogativa de delimitação de terras indígenas para o Ministério da Agricultura, Pecuária e Abastecimento (BRASIL, 2019) – que pode embargar o reconhecimento do novo território demandado pelo grupo.

O'Brien e Leichenko (2000) propõem o conceito de dupla-exposição (*double-exposure*) para expressar a ação combinada da mudança climática e da globalização sobre populações, grupos sociais e setores que, ao longo do tempo, encontram-se numa situação acentuada de vulnerabilidade. No caso do semiárido nordestino e SSF, os impactos da globalização se intensificaram a partir dos esforços modernizantes conduzidos pelo governo central entre as décadas de 1960 e 1980, visando inserir a região nas emergentes dinâmicas industriais e gerar crescimento econômico a partir dessa área. As hidrelétricas no vale do São Francisco foram um dos principais vetores dessa modernização à época, produzindo diversos impactos sociais e ecológicos locais (ANDRADE, 1984), inclusive a expropriação do território das comunidades que viviam no entorno do rio. O planejamento dos projetos, segundo Andrade (1984), teve ênfase nos aspectos técnicos e econômicos da produção de energia, não levando em conta aspectos locais: áreas agricultáveis, vilas e cidades foram inundadas. Somam-se aos efeitos desse processo modernizante dos meados do século XX – que ainda têm repercussões hoje – as dinâmicas mais recentes da globalização, notadamente a pressão fundiária para implantação de novos empreendimentos, como os parques de energia eólica no SSF. No entanto, tais iniciativas têm reforçado as desigualdades e vulnerabilidades socioambientais na região (MILHORANCE *et al*., 2019).

O Nordeste é uma das regiões brasileiras mais sujeitas aos efeitos adversos das mudanças do clima, deixando muitas populações desprotegidas (NOBRE; SAMPAIO; SALAZAR, 2008). No entanto, os povos indígenas, em geral, estão entre as populações mais vulneráveis. Além de sentir esses impactos, são afetados pelos efeitos adversos da globalização, que os tiram de seus costumes e os induzem ao trabalho remunerado e ao consumo de alimentos processados. Esses grupos vêm atravessando dificuldades econômicas e culturais devido à falta de demarcação de seus territórios. Devido à falta de espaços para a reprodução de sua cultura, e principalmente para a produção de alimentos de subsistência, encontram-se numa posição de exposição maior.

Segundo o Instituto Socioambiental (ISA), a terra ainda é a principal bandeira de reivindicação dos índios brasileiros. Apesar do direito estar ratificado por lei na Constituição Federal desde 1988, muitos povos continuam lutando pela retomada dos seus territórios tradicionais (ISA, 2007). Para os povos indígenas, a terra, além de ser um recurso natural e um meio de subsistência, agrega outros valores e representam a própria sobrevivência física e cultural dos povos. O ISA afirma que, na atualidade, no Nordeste, apenas 20% dos territórios indígenas estão demarcados, em contraste com as áreas indígenas da Amazônia, onde a demarcação atinge mais de 90% das terras.

Segundo o Censo de 2010, há 305 etnias indígenas no Brasil, as quais falam uma ou duas das 274 línguas identificadas. Essas etnias aglomeravam, naquele ano, 896,9 mil indivíduos, encontrando-se 36,2% em área urbana e 63,8% na área rural. O Nordeste contém 38 tribos indígenas, aglomerando 81 mil pessoas, o que significa 21% do total da população indígena do Brasil (IBGE, 2012). Entre esses

povos encontram-se os Tuxá, que esperam, hoje, assim como vários outros povos, a demarcação de seu território perdido após a construção da Usina Hidrelétrica Luiz Gonzaga (1985), que provocou a inundação de suas principais ilhas (VIEIRA et al., 2015)[7]. Segundo membros da comunidade Tuxá, no passado o território indígena estava composto por diversas ilhas fluviais localizadas entre Chorrochó (Barra do Tarrachil) e o Rio Pajeú, no estado Bahia, área que era de aproximadamente 1.600 ha (VIEIRA et al., 2015).

Hoje os Tuxá encontram-se divididos e espalhados em distintos grupos na Bahia (Municípios de Rodelas e Ibotirama) e em Pernambuco (Fazenda Funil), além de uma parte da população que migrou e se estabeleceu ao longo do tempo em Minas Gerais (Buritizeiro). No entanto, 30 anos depois de ter perdido seu território, ainda esperam uma justa compensação ou ressarcimento por parte da Companhia Hidroelétrica do São Francisco (Chesf) e do Estado, que ofereceram um restrito território em área urbana para o reassentamento da comunidade – em contraste com a vasta área em que cultivavam alimentos – deixando um sentimento de insatisfação, provocando a demanda pela delimitação de uma área adequada para a reprodução de seus costumes e produção de alimentos.

O deslocamento forçado, além de provocar a divisão dos Tuxá, gerou intensas mudanças no cotidiano do grupo, entre elas, perda de identidade, migração, pobreza e em algumas famílias deficiência alimentar. Segundo membros do povo indígena, a obra empreendida pela Chesf provocou o afastamento de seus ancestrais e territórios, seus valores étnicos e simbólicos, que se territorializavam em sua principal ilha, a Viúva. Weist (1995) afirma que as pessoas removidas involuntariamente devido à construção de projetos de desenvolvimento passam por luto, involução cultural e reestruturação de suas vidas, devido ao impacto que sua cultura sofre após perder a conexão com as acostumadas áreas ou territórios onde se deslocavam e se organizavam.

Dado que a cultura é o resultado de um processo de construção de identidades, levado adiante pelas pessoas e seus entornos, a paisagem forma parte da construção de identidade e cultura, que servem de suporte às suas representações. Duncan (1990) afirma que a paisagem é um dos fatores determinantes que permite a criação de cultura. No entanto, Cosgrove (1998) indica que a posse de terras ou território é muito importante, já que representa a disposição e possessão de fortuna, gerando conforto, segurança e estabilidade.

O território é o entrecruzamento do tempo com espaço a partir de memórias e imaginários territoriais. Forma parte de um sinal cujo significado só é compreensível desde os códigos culturais nos quais se inscreve. Ao contrário do espaço físico, tem uma significação cultural e implicações sociais, onde se estabelecem práticas sociais com interesses distintos, com percepções, valorações e atitudes territoriais diferentes, que geram relações de complementação e reciprocidade (GARCÍA, 1976; GOTTMANN, 1973). O espaço é uma atividade da alma, nela se inscreve a ação social e a ação recíproca como ato de preencher um espaço, formando associações mediante expressões. Existe uma relação importante entre sujeitos e objetos de um espaço, estabelecendo não só as características das sociedades concretas, mas também sua evolução temporal (SIMMEL, 1926, 1979).

Nesse sentido, o povo Tuxá, após sofrer o desterro, afastou-se de sua cotidianidade e alterou sua percepção de felicidade e riqueza, vivenciando a delimitação de sua evolução temporal e a perda de história e tradição que o valor simbólico do território lhe brindava, para além da própria capacidade prática de produzir o que consumia. Para alguns membros da comunidade, o afastamento de sua terra limitou aquela interação existente entre eles e os seus espaços sagrados, antigos e naturais, como as cachoeiras antigamente existentes, afastando-os de seus centros cerimoniais e diminuindo a convivência com seus ancestrais e divindades.

O povo Tuxá testemunhou uma quebra sociocultural devido à miscigenação de seus membros com população não indígena das cidades próximas, assim como o afastamento das práticas ancestrais de cultivo, a caça e a pesca, levando-os a assumir gastos que não tinham anteriormente, de alimentar

as famílias. Segundo membros da população indígena, as terras perdidas permitiam cultivar aproximadamente 100 hectares férteis, onde produziam arroz, cebola, árvores frutíferas, hortaliças, produtos que se adicionavam à alimentação diária das famílias, assim como peixes extraídos do São Francisco, ou carne de pecuária doméstica. Para muitos moradores de Rodelas, esses tempos são lembrados como períodos de abundância, paz e harmonia, lembranças que evocam saudade e revolta.

Na atualidade, segundo dados da Coordenação Técnica Local da Funai, em Rodelas-BA, das 490 famílias que moram na cidade, mais de 70% (424 famílias especificamente) recebem benefícios do programa Bolsa Família e uma cesta básica trimestralmente subministrada pela Companhia Nacional de Abastecimento – Conab (FUNAI, 2018). Isso evidencia a existência de famílias em situação de pobreza ou de extrema pobreza pelas baixas oportunidades de geração de renda, em parte devido à falta de território para o cultivo, o que as impede melhorar sua dieta atual e sua situação econômica, que poderia ser reforçada mediante a produção e comercialização de produtos agrícolas cultivados. Portanto, observa-se em Rodelas uma almejada delimitação do território Tuxá, situação que, segundo eles, permitiria reconstruir parte de sua história e promover o retorno àqueles tempos em que o cultivo no território lhes trazia abundância e lhes permitia ter assegurada uma boa alimentação, dentro do contexto de sua segurança alimentar.

4 PERÍMETRO IRRIGADO E SEGURANÇA HÍDRICA E ALIMENTAR: REALIDADE E PERSPECTIVAS

O SSF está integralmente dentro do território semiárido. Essa região possui longo histórico de convivência com períodos de secas, com baixa precipitação média anual associada a uma alta taxa de evapotranspiração (CBHSF, 2016). Segundo dados do Ministério do Meio Ambiente (MMA, 2017), em termos de aptidão agrícola, o Submédio possui apenas 7% de seu solo considerado como de bom potencial, sendo os 93% restantes classificados como regular, restrito, desfavorável ou desaconselhável. Mais recentemente, a região foi apontada, juntamente com outras áreas, como sendo de alto grau de desertificação (MMA, 2017).

Diante do cenário de seca, a redução da disponibilidade hídrica da Bacia na região semiárida limita o uso da água, seja para abastecimento humano, animal ou para o desenvolvimento de atividades econômicas. Apesar de não existirem terras mais adequadas para o desenvolvimento da agricultura de irrigação em toda a Bacia, a agropecuária é a que mais utiliza água, em torno de 540 m3 de vazão de retirada para cada R$ 1 mil de valor agregado bruto (VAB) (CBHSF, 2016). No Submédio, a demanda hídrica para irrigação pode ser superior a 10m3/s, como é o caso das sub-bacias Curaçá [Curaçá 01] e Rio do Pontal [Pontal 01], que compreendem os polos produtivos de Juazeiro-BA e Petrolina-PE (MMA, 2017).

Algumas políticas públicas vêm fomentando a adoção de sistemas de irrigação no semiárido, principalmente nos últimos 50 anos, como uma prática promissora para a produção de alimentos na região, atenuando os impactos da distribuição irregular de chuvas sobre as atividades agrícolas (CASTRO, 2018). Os Projetos Públicos de Irrigação (PPI ou perímetros irrigados) são um exemplo dessas iniciativas. Os perímetros possuem uma infraestrutura hidroagrícola, em partes de bacias hidrográficas, com a demarcação de lotes ocupados por agricultores irrigantes (MACHADO *et al*., 2017).

Os perímetros de irrigação fizeram parte do Programa de Desenvolvimento de Áreas Integradas no Nordeste (Polonordeste), no âmbito de um conjunto de políticas que tinham como objetivo formar polos de desenvolvimento nas áreas menos desenvolvidas e integradas do Brasil à época (Norte e Nordeste). Os polos receberam investimentos em infraestrutura de forma a receber atividades de maior geração de capital e promover uma "modernização conservadora" da economia local (ARAÚJO, 2000). Nesse sentido, esses locais, incluindo Juazeiro e Petrolina, tornaram-se manchas de maior renda e mais conectadas às economias mais dinâmicas do país, bem como a mercados externos. O Polonordeste teve também um propósito colateral de retenção dos fluxos migratórios que se originavam

no sertão em direção às capitais e outras regiões. Os polos de desenvolvimento tornaram-se centros intermediários que atraíam emigrantes da região ao seu entorno, por conta do dinamismo econômico do polo (BURSZTYN, 2008).

No caso do SSF, os perímetros irrigados estão concentrados no polo Juazeiro/Petrolina, o qual abriga sete PPIs, todos geridos pela Companhia de Desenvolvimento dos Vales do São Francisco e Parnaíba (Codevasf). O primeiro PPI foi implantado na região em 1968 e, desde então, já se tem uma área total de mais de 114 mil hectares. Nessas áreas, a maior produção é de frutas, principalmente uva e manga (SISPPI, 2018). O polo Juazeiro/Petrolina é considerado um exemplo de incentivo ao desenvolvimento de grande parte da cadeia produtiva, por meio da superposição de áreas de uma ampla produção agropecuária com a concentração de indústrias, promovendo modernização intensiva na região. O polo possui os maiores níveis de crescimento do valor agregado bruto (VAB) do setor primário no SSF na última década e uma tendência de crescimento apontada como muito alta (MMA, 2017).

Contudo, o último ciclo de seca na região tem gerado muitos impactos na atividade, ameaçando a sua segurança hídrica e alimentar. O Índice de Anomalia de Chuva (IAC)[8] para o total anual de precipitação para o município de Petrolina-PE, no período de 2010 a 2016, vem se mantendo negativo (à exceção do ano de 2014, que teve um tímido valor positivo), com três anos variando sua intensidade entre muito seco e extremamente seco (SILVA *et al*., 2017). Outro ponto importante a ser analisado é a disponibilidade hídrica do reservatório de Sobradinho, que fica a montante da área irrigada. Segundo dados da Agência Nacional de Águas[9], em novembro de 2017 o volume do reservatório de Sobradinho chegou a menos de 2% de seu nível máximo. Se considerarmos o início do período seco em 2010 (tomando como referência o IAC de Petrolina), em novembro daquele ano o volume útil do reservatório de Sobradinho fechou o mês em pouco mais de 33%.

O déficit de chuvas na região e a consequente redução do volume são fatores de exposição climática que influenciaram diretamente a gestão da Bacia. Já em junho de 2017, a ANA divulgou uma resolução que estabelecia uma medida de restrição de uso para captação de água superficial da Bacia, o chamado Dia do Rio, que acontecia às quartas-feiras. A restrição se aplicava inclusive ao uso de água para irrigação dos perímetros (ANA, 2017). Com uma nova resolução, em junho de 2018, as captações passaram a ser suspensas quinzenalmente, indicando uma melhora nas condições hidrológicas da Bacia (ANA, 2018).

Entre os grupos sociais do SSF, os agricultores familiares da área irrigada de Juazeiro/Petrolina perceberam os efeitos da seca mais tardiamente. Segundo os próprios agricultores, eles notaram os efeitos da seca apenas após o ano de 2016, e mais ainda depois das restrições de uso estabelecidas pela ANA em 2017. No entanto, mesmo antes desse período, irrigantes de alguns perímetros fizeram algumas mudanças no sistema de irrigação de suas propriedades. Por exemplo, os agricultores do perímetro de Mandacaru, em Juazeiro, estão usando gotejamento ou microaspersão para irrigar suas lavouras. Essa mudança no método de irrigação trouxe uma redução de aproximadamente 50% do uso de água e 30% da energia nas propriedades do perímetro ainda em 2013, segundo técnicos da Codevasf (FEITOSA; MACHADO; FRANCO, 2017). De certa forma, a associação da infraestrutura dos perímetros de irrigação com uma mudança nos sistemas de irrigação contribuiu para melhorar a segurança hídrica desses agricultores, já que para eles a disponibilidade de água não tinha sido afetada até esse período.

Outro impacto percebido pelos agricultores do perímetro foi o aumento de pragas nas lavouras. Eles afirmaram que, com a seca mais prolongada, as pragas não encontram refúgio na Caatinga seca e passam a afetar as lavouras irrigadas. Com o aumento do número de pragas, esses agricultores passam a usar mais defensivos agrícolas para manterem as lavouras produtivas. Esse uso intensificado aumenta o custo total de produção, que, na maioria das vezes, não pode ser repassado para os consumidores. Além disso, o maior uso de defensivos implica em consequências socioambientais (por exemplo, contaminação do solo e da água e problemas de saúde). No caso da poluição hídrica, o problema é agravado pela própria escassez, que acarreta uma menor capacidade de diluição das substâncias tóxicas.

Por outro lado, boa parte dos irrigantes dos perímetros não tem acesso direto a mercados consumidores, mas utiliza pessoas que funcionam como intermediários nessas transações. O repasse de produtos a intermediários reduz ainda mais a rentabilidade da produção desses agricultores, diminuindo também a renda familiar. Para manter sua segurança alimentar, muitos agricultores e suas famílias têm que complementar seus rendimentos com outras fontes de recursos, geralmente fora do empreendimento agrícola familiar. Para Sabourin (2014), o acesso a mercados adequados é um problema enfrentado pelos agricultores familiares: "uma das dificuldades das formas de agricultura familiar reside no acesso a mercados parciais e diversificados adaptados às suas características socioeconômicas específicas" (p. 21).

Uma alternativa seria a criação de cooperativas como forma de organização social para ampliar o acesso a mercados consumidores, ou mesmo o fortalecimento das associações constituídas de irrigantes dos perímetros, os chamados distritos de irrigação. Atualmente, essas associações são responsáveis principalmente pela administração, operação e manutenção da infraestrutura de irrigação de uso comum. No entanto, as decisões sobre produção e comercialização são tomadas individualmente, em cada propriedade rural. No caso do perímetro de Mandacaru, já havia sido criada uma cooperativa na década de 1980 como uma estratégia da Codevasf. Apesar de a Companhia avaliar os resultados da cooperativa do perímetro de Mandacaru como satisfatórios em relação à redução dos custos operacionais, a iniciativa não logrou sucesso, da mesma forma que outras cooperativas implantadas pela Codevasf nos distritos de irrigação. Os principais problemas que podem explicar o insucesso dessas cooperativas estão associados, principalmente, ao processo de implementação, a questões culturais e à falta de profissionalização na gestão desses empreendimentos (RIGO *et al*., 2008).

As perspectivas para a segurança hídrica das comunidades de irrigantes não são animadoras. Cenários tendenciais apontam para um balanço hídrico superficial crítico ou muito crítico para as sub-bacias do SSF, em 2025 e em 2035, mostrando um claro descompasso entre a demanda e a disponibilidade. No caso da agropecuária, mesmo adicionando um fator de análise da capacidade de satisfazer necessidades de água, o polo Juazeiro/Petrolina ainda apresenta tendência a um balanço hídrico superficial muito crítico nos dois anos considerados (CBHSF, 2016). Nesse sentido, constitui-se um desafio associar as perspectivas de disponibilidade hídrica com novas alternativas de uso inteligente da água na produção agrícola. Contudo, outros fatores que promovam a capacidade adaptativa desses sistemas socioecológicos merecem ser considerados (como o acesso a mercados adaptados às suas particularidades) na promoção da segurança hídrica e alimentar das famílias agricultoras do perímetro irrigado.

5 CONSIDERAÇÕES FINAIS

Nota-se, pela análise de distintos grupos vulneráveis, que a adaptação – como moderação das sensibilidades e fortalecimento das capacidades adaptativas – varia de acordo com as vulnerabilidades específicas das múltiplas e contrastantes realidades que convivem no SSF. A partir de uma visão sistêmica, pode-se compreender as potencialidades e possibilidades futuras para a região, definida como as propriedades dos sistemas sociais e naturais que favorecem a adaptação na presença de estresses climáticos. Os casos apresentados ilustram que a adaptação está condicionada às características físicas do local em que a população se encontra (como o regime de chuvas e proximidade de corpos hídricos perenes, fatores que condicionam o "risco"), mas também depende de uma ampla gama de fatores sociais, econômicos, culturais e políticos.

Para além das especificidades de cada população, é necessário considerar a interconectividade dos setores, escalas e atores, bem como abordagens integradas que minimizem as compensações e maximizem as sinergias entre as respostas das políticas setoriais. A interdependência da sociedade com o ambiente reflete a importância de análises e ações integradas que relacionem aspectos físicos, biológicos, sociais, políticos e econômicos, na busca de estratégias que promovam a resiliência de tais sistemas. Essa interdependência está bem representada, de um lado, pelos serviços ecossistêmicos (os benefícios às pessoas, produzidos e entregues por ecossistemas naturalmente funcionais, suas características, funções

ou processos ecológicos), que são os pilares que sustentam a humanidade e suas atividades (COSTANZA *et al*., 2017; CUMMING *et al*., 2017; MILLENIUM ECOSYSTEM ASSESSMENT, 2005).

Por outro lado, a interconexão da sociedade com o meio ambiente também é exemplificada pelas políticas que regulam o acesso e uso de tais serviços. A abordagem Nexus – que explora as conexões entre água, energia e alimento – figura como uma proposta para promover adaptações e resiliência de forma integrada. Os grupos estudados apontam para a relevância de abordar sobreposições e conexões nas adaptações, ou seja, as ações para a região devem abordar não somente as especificidades, mas a relação entre eles e o panorama sistêmico da região.

A falta de chuvas e a escassez hídrica evidenciam os diversos usos da água, e sobretudo os conflitos e potencialidades que emergem entre setores e grupos. A água na região é utilizada para o abastecimento dos centros urbanos por meio de represas e açudes; para o consumo humano e a produção de alimentos na agricultura familiar por via de açudes, poços, carros-pipa e tecnologias sociais de captação; a água represada que atende a esses públicos também serve à irrigação dos lotes de agricultura irrigada (tanto empresariais quanto familiares), e é utilizada para a produção de energia distribuída na região e fora dela. Nesse sentido, a água é um recurso que conecta uma diversidade de atores e interesses dentro da região e evoca a necessidade de políticas e abordagens analíticas que os compreendam de forma conexa, como postula o Nexus.

Os três grupos aqui trabalhados demonstram a pluralidade de impactos ocorrendo dentro de uma região que possui a mesma formação histórica e está sob o mesmo estresse climático, mas também permitem observar que as vulnerabilidades aparentemente específicas não podem ser compreendidas em isolado. A água para a produção de energia represada no lago de Sobradinho é a mesma necessária à irrigação dos perímetros agrícolas de Juazeiro e Petrolina. A geração de eletricidade gera conflitos de interesse de natureza distinta a 300 km a jusante, onde os Tuxá ainda tentam recuperar suas dinâmicas produtivas e culturais, 30 anos depois da inundação do Lago de Itaparica. A 120 km de distância, os desafios da atividade rural em Juazeiro/Petrolina e em Uauá ilustram os contrastes herdados pela própria ação (ou omissão) pública no passado da região: a segurança alimentar e de renda das comunidades de Fundo de Pasto ainda se encontram sujeitas à variação das chuvas e das incertezas quanto à regularização fundiária, em oposição aos perímetros públicos irrigados, que não sentiram tão intensamente os efeitos de seis anos de seca, mas que não têm a capacidade de mobilização das comunidades tradicionais.

Assim, a adaptação ao clima e, de forma mais ampla, o desenvolvimento sustentável de regiões como a exemplificada pelos estudos realizados no SSF dependem da compreensão de sua heterogeneidade e complexidade, assim como das conexões que se estabelecem dentro da sub-bacia e para além dela.

NOTAS

1 | Agenda 2030. Disponível em: https://nacoesunidas.org/pos2015/agenda2030/.

2 | Política Nacional sobre Mudança do Clima (PNMC), Lei 12.187, de 2009. Disponível em: http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2009/lei/l12187.htm.

3 | Plano Nacional de Adaptação (PNA). Disponível em: http://www.mma.gov.br/clima/adaptacao/plano-nacional-de-adaptacao.

4 | O IAC é um método de avaliação das mudanças climáticas em nível local com base no comportamento do regime pluviométrico (SILVA *et al.*, 2017). O IAC analisa a frequência e a intensidade de anos secos e chuvosos. Se for positivo (anomalia positiva), indica que os valores observados estão acima da média histórica de precipitação na região. Se for negativo (anomalia negativa), indica que o volume de chuvas foi menor que a média histórica (SOBRAL *et al.*, 2018).

5 | A Razão Intercensitária de Sobrevivência (RIS) provê indicativos da saída de jovens da zona rural na região do submédio. A RIS é a diferença de um recorte populacional entre um Censo Demográfico e o censo anterior. Nesse sentido, reflete a diminuição (valores menores do que 1) ou aumento (valores maiores do que 1) da população de uma determinada faixa

etária. Nos casos de RIS negativa, o valor pode indicar três diferentes fenômenos: i) emigração, ii) mortalidade e iii) mudanças na definição dos espaços rurais e urbanos entre os dos censos (MAIA; BUAINAIN, 2015).

6 | Diferença entre população imigrante e população emigrante, sobre população total da região, multiplicado por 100.

7 | A Usina Hidrelétrica Luiz Gonzaga (antes conhecida como Usina Hidrelétrica de Itaparica) está localizada nos estados brasileiros da Bahia e Pernambuco. Pertencente à empresa Chesf, foi renomeada em homenagem ao cantor e compositor brasileiro Luiz Gonzaga do Nascimento (1912-1989).

8 | Método de avaliação das mudanças climáticas em nível local com base no comportamento do regime pluviométrico (SILVA *et al.*, 2017).

9 | Dados do Sistema de Acompanhamento de Reservatórios/SAR. Disponível em: http://sar.ana.gov.br/MedicaoSin. Acesso em: dez. 2018.

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The Tuxá indigenous social network, interaction and exchange of information for the promotion of adaptive measures in the face of climate change

A rede social indígena Tuxá, interação e troca de informação para a promoção de medidas adaptativas ante as mudanças climáticas

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ABSTRACT

Studies show Social Network Analysis (SNA) as a successful methodology within the environmental sciences. In the present study, this methodology was implemented in the Tuxás indigenous community in Bahia-Brazil, to understand the configuration of interaction and information flow of the people and their multilevel relationship to face the environmental problem of drought. By creating networks by scale, we identify actors and their roles within the community, characterising the centrality of actors and their internal and external relationships to create adaptive strategic actions that strengthen the links between them and local and regional initiatives. For data collection, structured interviews were conducted with key informants using the snowball methodology. As a result, the SNA made it possible to identify links, bottlenecks and potential institutions to reduce the vulnerability of the traditional population and to identify adequate ways to promote adaptation and solve environmental problems.

Keywords: Social Network Analysis. Indigenous Peoples. Adaptation. Vulnerability. Adaptive measures.

RESUMO

Estudos mostram a Análise de Redes Sociais (ARS) como uma exitosa metodologia dentro das ciências ambientais. No presente estudo essa metodologia foi implementada na comunidade indígena Tuxás da Bahia – Brasil, com o intuito de compreender a configuração de interação e fluxo de informação do povo e sua relação multinível para enfrentar a problemática ambiental da seca. Identificamos mediante a realização de redes por escalas, atores e seus papéis dentro da comunidade, caracterizando a centralidade dos atores e as suas relações internas e externas para projetar a criação de ações

estratégicas adaptativas que fortaleçam os vínculos entre eles e as iniciativas locais e regionais. Para a coleta de dados, foram realizadas entrevistas estruturadas a informantes-chaves usando a metodologia bola de neve. A ARS permitiu identificar elos, gargalos e potenciais instituições para diminuir a vulnerabilidade da população tradicional, assim como identificar caminhos adequados para promover adaptação e dar solução a problemáticas ambientais.

Palavras-chave: Análise de redes sociais. Povos indígenas. Adaptação. Vulnerabilidade. Medidas adaptativas.

1 INTRODUCTION

Carrying out an SNA makes it possible to describe, quantitatively and qualitatively, important points of social phenomena linked to other specific themes, such as health, ecosystem, cultural, and environmental problems, among others (BERKHAM; GLASS, 2000; WASSERMAN; FAUST, 1994). As a result, interest in carrying out this type of analysis has grown in recent years in several research areas (FONTES; EICHNER, 2011; GOMIDE; SCHÜTZ, 2015; RIBEIRO; BASTOS, 2011).

Within the environmental and social sciences, some studies assess issues related to climate change and the establishment or measurement of adaptation mechanisms. However, these are mostly carried out outside the country and focus their attention on two aspects: 1) Network analysis existing institutions that address climate change, its impacts and adaptation mechanisms (BICKEL, 2017; CEDDIA, 2017; CORLEW, 2015; ISLAM, 2017; JAJA, 2016; JONES, 2014) and 2) Feasibility studies of adaptation in specific local communities (ANDRÉ, 2017; CHAUDHURY, 2017; DONG, 2017; FARRELL, 2015; NOH, 2015; RECKIEN, 2012; SCHRAMSKI, 2016; ZIERVOGEL, 2017).

In this article, we present how the analysis of social networks can contribute to implementing adaptive measures in the Tuxá Indigenous community of Bahia - Brazil. These people are located in three Brazilian states: Bahia, in Aldeia Mãe Rodelas and D'zorobabé; Fazenda Sítio, Indigenous Land, Ibotirama and Remanso Farm Indigenous Reserve; Pernambuco, in Inajá/Fazenda Funil and Kambiwá Tuxá (border Pernambuco/Alagoas) and Minas Gerais, Buritizeiro. Their dispersion is the result of the construction of the Luiz Gonzaga Hydroelectric Power Plant in 1988, which, according to studies carried out by Bernal and Rodrigues Filho (2020; 2021), generated alarming socio-environmental impacts on the indigenous group, including: intense changes in daily life, loss of identity, migration, division, poverty and, consequently, food and water deficiency, which, due to territorial loss and the impacts of extreme events produced by climate change, has been intensifying.

Knowing this situation, there was a need to implement adaptive measures to reduce the population's vulnerability. In this sense, in order to identify the main ways for its establishment, we have developed three social networks, identifying, on the one hand, the potential bottlenecks and, on the other hand, the ways that can contribute to the implementation of adaptive measures more effectively, dealing with the Tuxá problem from scaled interconnectivity. The study analyses four networks: the exchange of information about the drought of the Tuxá people, the network of potential social bottlenecks, the network of social and institutional connections for adaptation, and adaptive multiscalarity. We identified the density of the people's communication network and the centrality of individuals, and such results served as a basis for analysing the collaborative relationships between those involved.

2 LITERATURE REVISION

2.1 THE COMPLEMENTARITY OF SOCIAL NETWORK ANALYSIS (SNA) AND ITS APPLICATION IN VULNERABILITY AND ADAPTATION STUDIES

The SNA is a methodology used for decades in different areas of knowledge. It permits identifying social interactions and studying existing networks, whether informal, spontaneous or unintentional (GROSSETTI, 2003; 2004), as well as making it possible to analyse the structure of existing connections between individuals in a given social context (TOMAEL; MARTELETO, 2013).

Recent research claims that SNA became a common denominator in dealing effectively with socio-environmental problems (BODIN, 2009; BURGOS; MERTENS, 2017; VELÁZQUEZ *et al.*, 2005). Within the surveys that show how the application contributes to understanding social vulnerability in the face of the effects of climate change, some carry out specific assessments on individuals and social groups concerning the problem. However, others analyse how institutions, implemented public policies, trust and communication in networks are essential to practice efficient adaptation measures.

Kate *et al.* (2015), for example, assess the structural nature and extent of climate-based communication among Pacific Island professionals; the authors identify key regional centres and isolated clusters to create a set of place-based tools that would enhance and facilitate the linking of different climate change resources (human, economic, research and adaptation). The study's results reveal a diffuse and strongly connected network without isolated spatial or sectoral groups.

In the same year, Matthew (2015) criticises the use or interpretation of poverty as an indicator of vulnerability because social relations, according to him, shape the multidimensionality of vulnerability. Analysing members of 54 families in Nigeria, the author shows that poverty by itself is an incomplete measure of the vulnerability of an individual or a household due not only to the randomness of biophysical risk but also to different obligations and rights associated with wealth. The analysis done by the author shows that young women and men tend to gain more wealth compared to older men, and the gains of healthy women do not reflect their lower vulnerability compared to older men but rather their strategies to approach their vulnerable positions.

Studying the arid and semiarid zones of North Africa and the Middle East, Alary (2016) shows the existence of a link between family livelihoods and the social capital of Bedouin society and an important link between physical assets, nature, the level of education and the intensity of social ties within traditional society. This study presents particularities similar to that developed by Matthew (2015). In both, an individual's vulnerability is due not only to the randomness of the risk or a particular factor but also to the sum of aspects that make the individual and society more vulnerable.

Analysing disaster management and climate change policies in Bangladesh, Islam and Walkerden (2017) assess how they do or do not consider families' social networks. This study shows that, despite the importance of social networks in resilience and disaster recovery, these are not emphasised in government policies. However, organisations that link social networks (i.e. links of governments with organisations, states, donors and others) do. On the other hand, family bonding networks (relationships with family members and immediate relatives), bridging networks (families' relationships with neighbours and friends) and their local bonding relationships (mainly with non-governmental organisations (NGOs) and local government) are largely ignored.

It is observed that there is a need to incorporate studies that permeate these unitary scalar analyses, such as the incorporation of multilevel studies that clearly show the existing connections within a particular society and their interaction with other sectors and levels of the same society, guaranteeing, on the one hand, understanding the social characteristics of the group, and, on the other hand, calling

the attention of sectoral and governmental authorities, who, based on concrete data, propose plans, actions, projects, measures or concrete policies in line with reality and needs.

For example, Chaudhury *et al.* (2017), examining the connectivity and positions of vulnerable rural communities, families and their adaptability in Ghana, show that some external relationships expose families to misinformation and ignorance, as well as to other forms of capital, which in turn, strengthen their ability to access and mobilise resources to respond to environmental changes. The authors state that not all external relations have equal access and that the adaptation capacity of families within the community is stratified.

As seen in this study, the authors identify points at which local actors can link communities and households with key cooperating agencies to plan and implement effective adaptation. At this point, we refer to when a multiscale analysis on the subject would allow a real understanding of the Tuxá society, its vulnerability and the existing possibilities to make its adaptation viable. Some works carry out this type of analysis. Ernstson (2008), for example, considering the patterns of interaction between organisations, reveals that a core-periphery structure of central and semi-central organisations can build political connections with the authorities, where the periphery brings together all groups of users involved in daily activities, facilitating processes of collective action for protection. A few years later, Ernstson (2010) also showed how government agencies and civil society groups engaged in urban area management could connect through social networks to combine spatial scales of ecosystem processes.

This last work is one of the most important within the multiscalar analysis since, by making a structure, it unites ecological scales with structures of social networks, the latter being taken as patterns of interaction between groups of actors. The article shows that functionally interconnected local green areas are not addressed by any actor in Stockholm and that the management practices of civil society groups involved in local ecosystem management are crucial but regularly neglected. Finally, Cash (2006), by analysing the cross-scale in managing the environment, showed great complexity in analysing interactions. However, he states that the interaction between institutions on multiple levels and scales affects the dynamics of cross-scale interactions and between levels.

3 STUDY METHODOLOGY AND DATA PROCESSING

Methodologically, the study is qualitative and based on the research protocol of the 2014 Climate Change and Regional Development Sub-network in Brazil and the methodological procedures for carrying out the Social Network Analysis (SNA). The Climate Change and Regional Development Sub-network of the Climate Network of Brazil has a document called research protocol, which is currently used in research that incorporates analysis of Climate Change and its impacts, allowing the realisation of socio-environmental assessments recognised nationally and internationally.

Primary data were collected through structured interviews in the Tuxá indigenous community located in the semiarid region of the municipality of Rodelas-Bahia (see Figure 1). Data were collected in two field visits; the first in October 2017 and the second between November and December 2018.

The number of interviews was determined using the snowball methodology, allowing to reach the most prominent informants in the community, among them: leaders, teachers and indigenous representatives, who showed knowledge about the history of the people, the impacts of extreme events and about the decisions established in the community.

In total, 97 structured interviews (68 in Rodelas and 29 in Surubabel)) were applied to men and women from different areas to understand how this social group interacts internally and externally in the context of themes and knowledge about the impacts of droughts caused by climate change. The

networks presented in the study result from specific questions duly consolidated in a database and processed in the Ucinet and NetDraw software.

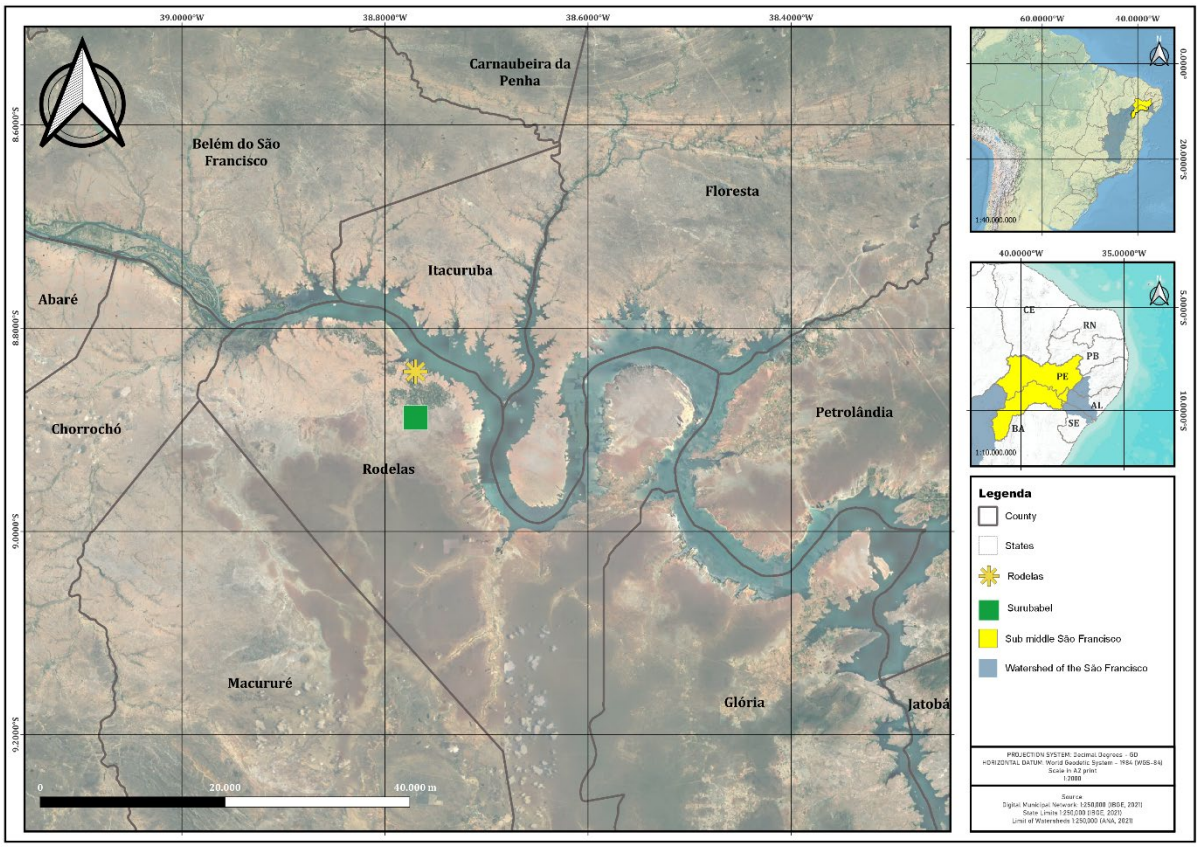

Figure 1 | Survey primary data collection areas

Source: Elaboration of the authors

Finally, it should be noted that this study meets the standards and requirements of the Research Ethics Committee of the Faculty of Human and Social Sciences of the University of Brasília (UnB), process duly registered in protocol No. 01037218.5.0000.5540 and approval No. 3.440.

4 RESULTS

4.1 THE TUXÁ DE RODELAS DROUGHT INFORMATION EXCHANGE NETWORK

Preparing and analysing the first network shown in Figure 2, it is noticed that, commonly, members of the indigenous people tend to talk about the drought and its consequences, mainly in those population that has a degree of representativeness, leadership and confidence (see Figure 2). A significant proportion of the population tends to dialogue specifically with five individuals who have an important degree of centrality within the people. This fact allows us to notice an adequate way to facilitate greater communication since their involvement with the population, their representativeness and ease of communication with a large number of people would enable better implementation of activities or local adaptive measures.

This network has a density of 0.2, which, contrary to presenting a saturation by interrelationships, is adequate since very high densities can lead to homogenisation and redundancy of knowledge, reducing

the effectiveness of collective action and the ability to adapt (BODIN, 2006; BURGOS, 2014). Existing links show an important connection between certain individuals, which helps us see the most representative.

To promote adaptive measures or implement public policies within the indigenous community, one can seek to gradually increase the network's density by promoting dialogue among the local population, a fact that would help make the actions carried out in the community more efficient.

The second network identifies active community members with an effective approach to institutions. We observe that five individuals are the most cited, constituting the most representative and, in turn, strategic actors to boost some activities, since, through this analysis, it is possible to identify the degree of importance that each actor has, their position within the community in relation to intercommunication, prestige and representativeness, in order to identify the influence that each one has on the population and at an institutional level.

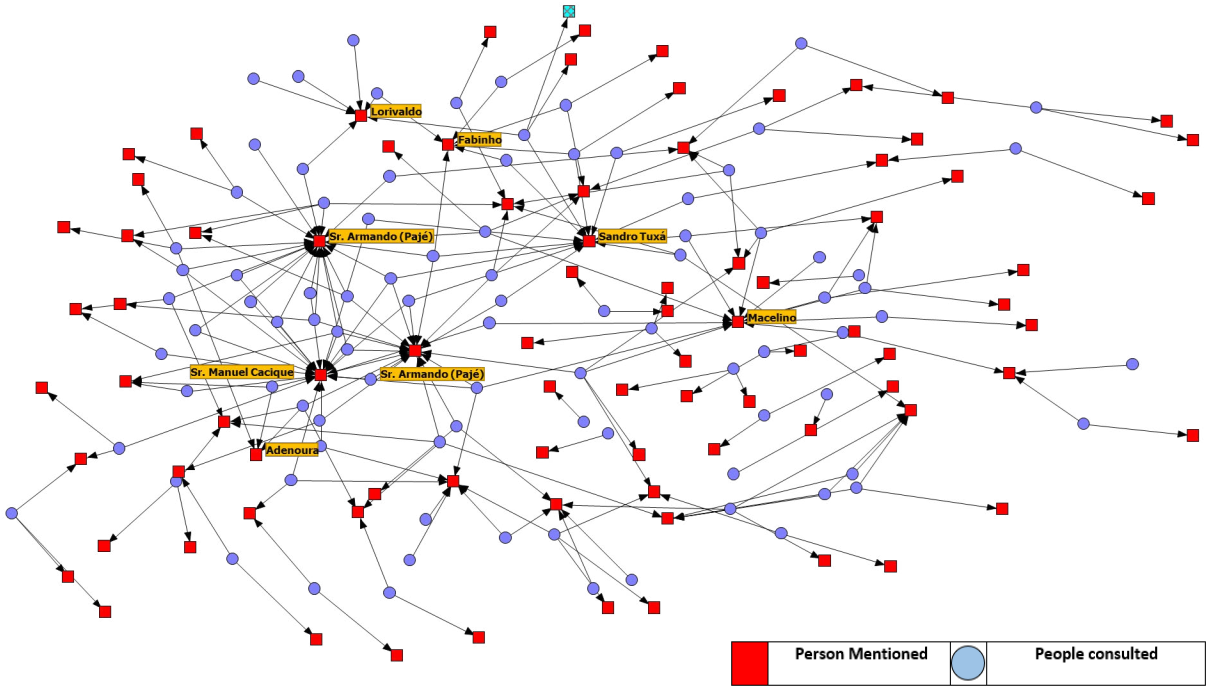

Figure 2 | Drought information exchange network

Source: Elaboration of the authors

Observing Figure 3, we can see a division in the population's perception of the representativeness of the actors. Some claim that the oldest representatives of the community are the ones who have the most contact with different institutions. However, other groups claim that active young people are the ones who interact the most. This perception is fundamentally due to two factors: the age of the people consulted and the role of the individuals.

Regarding the first point, it was identified that people over 40 years of age, for the most part, identify Mr Armando and Manuel as the actors who interact more with institutions. However, for younger people, they are Sandro Tuxá, Antônio Fernandez (Dinamam) and Uilton Tuxá. In relation to the older representatives of the community, it is observed that whoever appoints Mr Manuel (Cacique Bidú) as an articulator with different institutions are mainly housewives, retirees and older civil servants, noting here that representativeness is given by generation. Regarding the second factor, it is observed that Dinamam is indicated mainly by civil servants, students and farmers and Sandro Tuxá by civil servants, fishermen and retirees from the community, a fact based on the active function *in situ*.

The network makes it possible to identify the main people who maintain a significant relationship with institutions and their relationships in the community. Having presented the network to the population, it would generate greater confidence and discourage other isolated ones, aiming to bring together less representative actors. Therefore, the most appropriate paths for implementing adaptive measures, public policies or projects in the indigenous community are observed.

An adequate approach and activities focused on groups and directed by the most representative social actors would make it possible to obtain the expected results in the best way. Starting activities only with leaders does not guarantee success since personal factors of leadership and the adjacent actors also become determinants, because in many cases, successful projects and policies result from the generation of actions, the transmission of information, empathy, coordination and mediation, enabling the assimilation of actions, procedures and information.

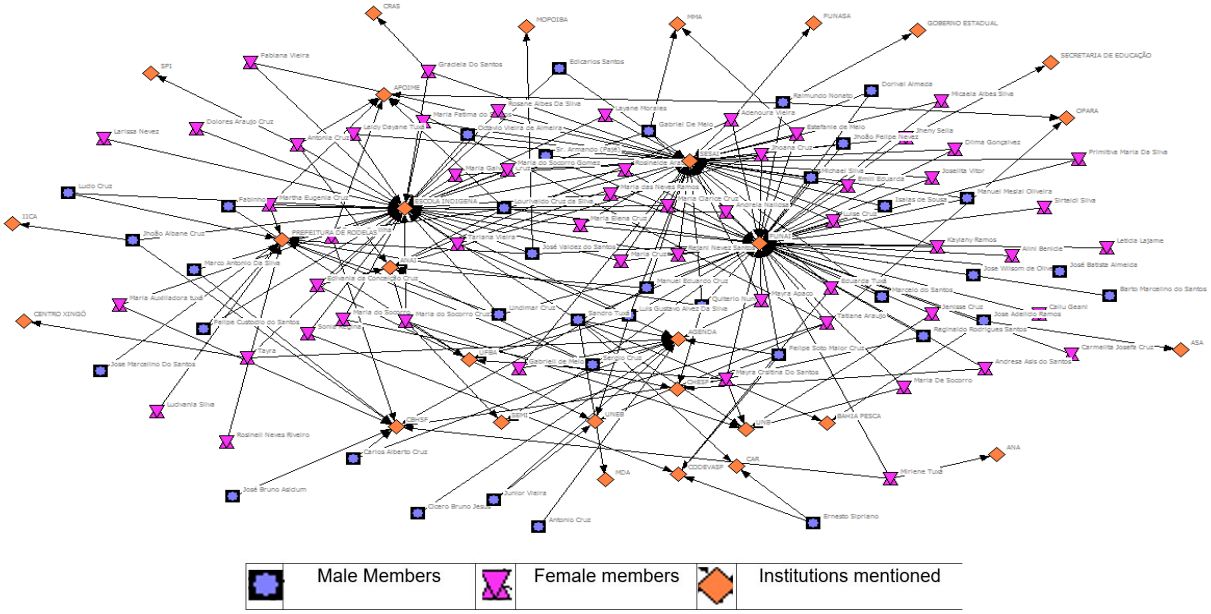

Figure 3 | Network of indigenous representatives before public and private institutions

Source: Elaboration of the authors

4.2 THE IMPORTANCE OF INSTITUTIONS TO FACE CLIMATE CHANGE IN RODELAS

The strengthening and creation of institutions in evaluating and implementing adaptive measures to reduce the exposure and sensitivity of the vulnerable population become a determining factor (IPCC, 2014). In Brazil, over the last 20 years, the Amazon fund was recently reactivated and financed by donations from various governments and projects from multilateral institutions, non-governmental organisations (NGOs), companies, and public institutions that helped generate policies to mitigate climate change.

Advances in issues such as access to water, food, income generation, and agriculture, among others, have reduced poverty in some regions of the country and the exposure and sensitivity of the poor population to climate change. However, the development of projects and adaptation policies is still deficient. Rodrigues Filho (2016) states that Brazilian action in the face of climate change has been developed at a political-institutional and legislative level, mostly focusing on actions aimed at mitigation, leaving adaptation in a marginal space. In this sense, since Brazil is a country with a high vulnerability, it becomes urgent to include this point effectively in the national and institutional agenda (LINDOSO, 2013). Therefore, a continued effort and a global approach aimed at identifying strategies, policies and

instruments that strengthen institutions and develop effective measures to face the impacts of climate change are indispensable.

Through understanding the situation of vulnerability of the Tuxá indigenous people (BERNAL, 2021a; 2021b) and after identifying possible managers for the implementation of adaptive measures through the population's reports, it was verified the existence of 29 institutions that, over the past 15 years, have supported the people with various socio-environmental initiatives (see Table 1), including projects to improve income and access to water, as well as developing local capacities and combating drought.

Among the activities to face the drought, it is stated that the construction of dams was promoted, the acquisition of seeds and animals for agriculture and livestock, the strengthening of indigenous fish farming, the drilling of wells and more of the population's direct actions, such as assistance with food distribution, strengthening of public health, creation of alternative sources of work, among others.

Community leaders indicate that many projects generated positive results during their implementation. However, they claim that once they ceased to be monitored by the institutions, the projects and results began to decline. However, they state that the benefits were positive since, without them, the impacts of the last drought recorded between 2014 - 2018 would have caused greater losses for the local population.

Table 1 | Institutions that support the Tuxá people to face the Drought

Initials	*Institution Name*	*Initials*	*Institution Name*
AGENDA	Advice and Management in Nature Studies, Human Development and Agroecology	FUNASA	National Health Foundation
A-N-A	National Water Agency	STATE GOVERNMENT	State government
ANAI	National Association of Indigenous Action	IICA	Inter-American Institute for Cooperation in Agriculture
SUPPORT	Articulation of Indigenous Peoples and Organisations of NE, MG and ES	INSA	National Institute of the Semiarid
WING	Brazilian semiarid joint	MDA	Environmental Program of the Ministry of Agrarian Development
BAHIA PESCA	Bahia Pesca Government of Bahia	MMA	Ministry of the Environment
CAR	Regional development and action company	MOPOIBA	United Movement of Indigenous Peoples and Organizations of Bahia
CBHSF	São Francisco River Basin Committee	COJIPE	Pernambuco Indigenous Youth Commission
CX	Xingó Center	PR	City Hall of Rodelas
CHESF	San Francisco Hydroelectric Company	DEPARTMENT OF EDUCATION	Department of Education
CODEVASF	São Francisco and Parnaíba Valley Development Company	SESAI	Special Secretariat for Indigenous Health
CRAS	Social Assistance Reference Center	SPI	Indian Protection Service
AND GO	Indigenous School of Rodelas	UFBA	federal university of Bahia
FUNAI	National Indian Foundation	UNB	University of Brasilia
UNEB	State University of Bahia		

Source: Elaboration of the authors.

According to the SNA results and the perception of the Tuxá people, the institutions that most support the population are: Funai, the Rodelas indigenous school, Sesai, the Rodelas city hall, the CBHSF and the organisations Anai, Apoime and Agendha, institutions that, as they say, have become key to facing the

difficulties caused by climate change (see Figure 4). For example, they indicate that the indigenous school, Funai and Sesai support capacity building, sanitary improvement and food distribution, components considered essential to generate a better adaptation and coexistence with the drought. At the same time, CBHSF and Agency Agendha carried out water availability projects, helping to face the problem of drought.

Effective implementation of the proposed strategic lines for adaptation and mitigation requires consolidating public policies and adequate work between social actors and institutions. The human characteristics, potentialities and knowledge of the individuals involved become unnecessary if organisations and institutions do not value or promote them to plan projects or adaptive measures.

In this sense, we see how important it is to consider each suggestion and knowledge of the local population when planning and generating targeted policies. Alary (2016), Chaudhury *et al.* (2017) and Islam and Walkerden (2017) state that the understanding of cultural aspects and knowledge of the traditional population, added to an adequate support from organisations, governments and donors, allow the adequate design of adaptation policies and projects, guaranteeing excellent results at the time of their application.

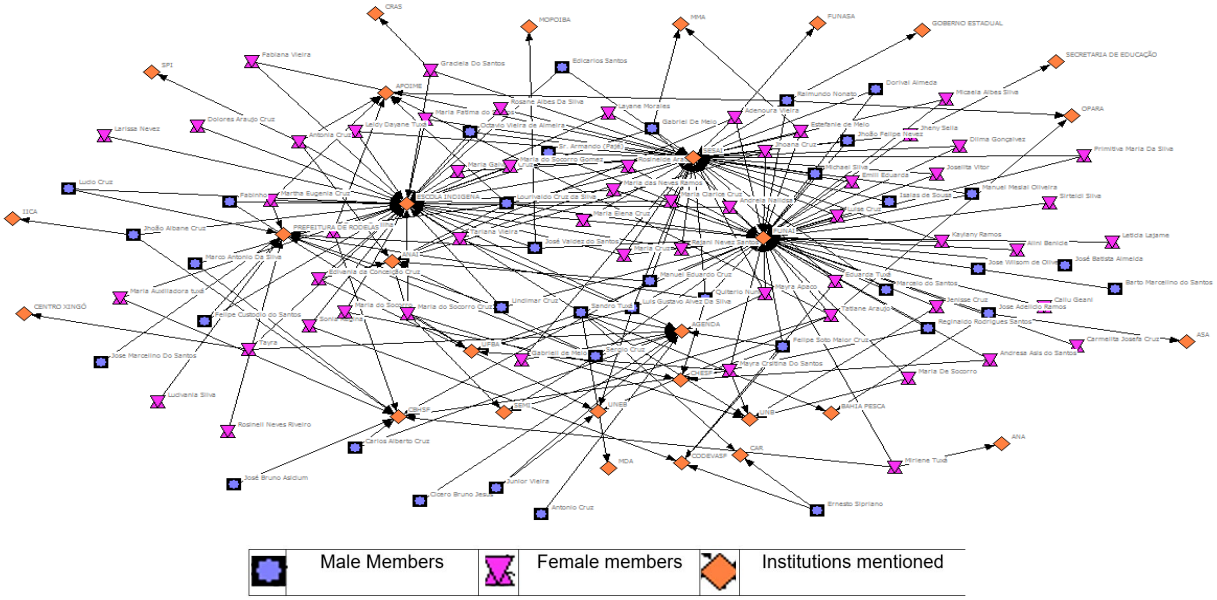

Figure 4 | Identification of institutions that have been supporting the Tuxá population to fight the Drought

Source: Elaboration of the author

These aspects are considered a new form of non-shared institutionality, horizontal coordination and integration of technical capabilities. The network shown in Figure 4 allows us to see the institutional ways that would help to better face the impacts of drought on the indigenous territory, where the institutional structure, linked to the population's collective actions, becomes effective in guaranteeing coordination and adequate integration to lessen vulnerability. Therefore, the involvement of a greater number of institutions and social actors can lead to better results and adequate and effective planning and implementation of adaptation within the community (CHAUDHURY *et al.*, 2017).

4.2 ADAPTIVE MULTISCALARITY AND NETWORK INTERCONNECTIVITY TO ENSURE TUXÁ ADAPTATION

According to Engle (2011) and other authors, the determinants to achieve an adequate adaptive capacity established by the IPCC (2007) include the involvement of economic resources, technology,

information, infrastructure and institutions (SMIT; WANDEL, 2006). In Sociological, Political Economy and Geography studies, adaptive capacity is related to the ability to act collectively, where social capital, trust and organisation are important (ENGLE, 2011; LEMOS, 2016; PELLING; HIGH, 2005).

In this sense, the generation of adaptive capacity depends on the availability of infrastructure, economic and technological resources, and social factors, such as social capital, coordination, information flows, trust, and willingness to learn and transmit knowledge (EAKIN; LEMOS, 2006). To reduce the vulnerability of the Tuxá indigenous population, some social technologies were identified as adaptation measures for the population (see Table 2). However, analysing the social context and the networks established so far, it is considered that they should be implemented through multiscalarity and interconnectivity.

The traditional way of conceiving science often meant that social and environmental issues were studied in a fragmented way. However, in analyses of conservation and the use of natural resources in the environmental sciences, it allowed associating these problems and analysing them under a differentiated model, making it possible to understand them better (MONTAÑEZ, 2005). These new analysis processes gave rise to the "*multiscalar*" concept, where different levels of participation and complexity, including: geographic, social, political, and ecosystem aspects enter into a joint analysis comprising contexts, realities and local specificities (CASH, 2006).

"Multiscalar" analytical approaches are particularly appropriate to understand this relationship between man, population mobility, environment, land use, and generation of public policies, among others, in different but interconnected scales and levels of spatial and temporal analysis (BARBIERI, 2007; CASH, 2006). The process of social dynamics, especially in multiscalarity, is considered from at least three elements: flexibility, discontinuity and superposition (COELHO, 2013). Another relevant aspect of multiscalarity from a more social perspective is the centrality of the notion of power, where the complex power relations between the most varied agents that operate at multiple scales allow analysing the multiscalarity of the territory, a society, public policies and the interaction of actors where power is manifested and exercised (COELHO, 2013).

Carrying out a multi-scale analysis applied to the evaluation of the different networks elaborated so far, we observed in the Tuxá people's information exchange network about the drought that the indigenous population, preferably, tends to talk about the subject with five central actors of the community who, in turn, are representatives of the community and are dedicated to different economic activities. However, they concentrate information, knowledge about the indigenous reality, and confidence and power over the rest of the population, factors that can be used when implementing the proposed adaptive measures.

Table 2 | Proposed adaptation measures

System	*Description*	*Source*	*Guiding Institutions*	*References*
Recovery of Springs	Recovering or protecting a spring area, in addition to being an environmental investment, helps guarantee the water supply in the countryside and maintains local biodiversity.	Technology available on the market	Xingó Center	Gualdani, et al. al. (2015)
Plant genetic improvement	Genetic improvement of rainfed crops for the semiarid region, used in family production systems, aiming at obtaining plant materials tolerant to drought and high temperatures.	research and development	Embrapa Semiarid, IPA	Costa et al., (2005); Santos et al., (2008)

System	Description	Source	Guiding Institutions	References
Well Cacimbão	Small depth excavated well that exploit the groundwater to supply water for animals and irrigation.	Technology available on the market	Xingó Center	Gualdani, et al. al. (2015)
Selection of rhizobium strains for legumes	Selection and recommendation of autochthonous semiarid rhizobia strains for inoculation of cowpea cultivated in the semiarid region.	Technology available on the market	Embrapa Semiarid, Embrapa Agrobiology and UNEB	Martins et al., (2003)
Eco Stove	More efficient model that reduces wood consumption between 40% and 50%. Saving firewood and reducing smoke emissions. As it is closed, it does not emit smoke or soot in the environment where it is installed, which will make the environment hygienic, clean and healthy for families.	Technologies transferred	Xingó Center	Gualdani, et al. al. (2015)
In situ water collection systems	Rainwater harvesting technologies: underground dams, cisterns, lifeguards	Technologies transferred	Embrapa Semiarid, IRPAA	Lopes and Brito (1998); Brito et al. (2008)
Biodigester	Equipment that produces biogas and biofertiliser, through fresh animal feces and water, at room temperature (20°C to 45°C). Production of biogas and biofertiliser (fertiliser), reducing the consumption of cooking gas sustainably.	Technologies transferred	Xingó Center	Gualdani, et al. al. (2015)
Construction of plant nurseries: family fish farming.	Improvement of the productive management of indigenous fish farming.	Technologies transferred	Embrapa Fishing and Aquaculture	Lima, A.; Prysthon, A.; Guedes, C .; Bergamin, G.; Pedroza, M. (2012)

Source: Elaboration by the authors with data from Angelotti (2011) and Gualdani et al. (2015)

These individuals, empowered with a greater degree of centrality (which also means greater linkage with other actors), would help disseminate information on the adaptive measures and their better implementation. However, for this to happen, a wider interconnection and communication between these central actors, the population at large and the institutions that implement projects in Rodelas, observed in Figure 3, must be promoted.

In this network, we observed that three individuals mainly have greater contact with institutions and represent groups divided by generation and economic activities. Both Sandro and Mr Manuel are part of the indigenous people's information exchange network, constituting themselves as key actors and interlocutors between indigenous society and institutions, and are also part of the second network. However, we observe that it is necessary to establish an effective articulation between these individuals and Dinamam Tuxá, positioned at the level of indigenous representative before institutions with a high degree of centrality (see Figure 3). This factor will more effectively promote an adequate escalation before the institutions since the mentioned actor exerts a strong representation of the indigenous peoples in the region and Brazil.

Interconnectivity is another determining factor for the successful establishment of initiatives. Observing possible connections between different individuals in the community (see Figure 5): central actors (first level), interlocutors of the groups with institutions (second level) and institutions active in the region (third level); and adequate synchronicity when planning and implementing adaptive measures

for the Tuxás, would allow effective and lasting results, which not only materialise in the short term but rather establish themselves as solid long-term projects.

Projects implemented in different contexts often lose momentum as soon as the promoters leave. This type of implementation, which prioritises interconnectivity and the escalation of interactions regarding specific problems and solutions, aims to guarantee the success of the implemented initiatives, as well as to generate sustainability since both needs and possible solutions arise from the population. The linking of strategic individuals from the beginning up until the consolidation of initiatives can promote greater belonging to the final result, leading to the actions, initiatives and knowledge transmitted to the population to remain.

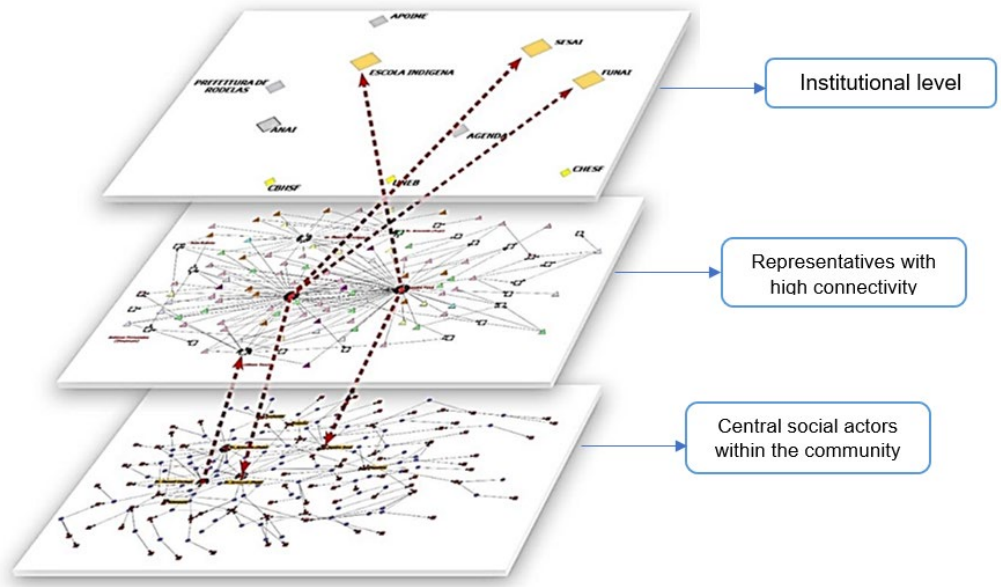

Figure 5 | System of interconnectivity of social actors and institutions. Multiscalarity for the implementation of adaptive measures

Source: Elaboration of the authors

So far, it has been observed that the SNA makes it possible to identify links or bottlenecks and potential institutions to reduce the vulnerability of the indigenous people, proving that an integral and multiscale analysis helps to identify these aspects, as well as to propose the most appropriate paths. It was shown that this approach allows to create adaptive capacity that is hardly generated in isolation but rather from the identification of demands, knowledge of families and actions of remote agencies, mitigating the risks related to the impacts of climate change.

In this scenario, the central actors and indigenous leaders play an essential role, and the recurrent situation in the daily life of individuals requires them and the rest of the group to reorganise in favour of adaptation. However, the indigenous representatives must seek funding from institutions, local, private and public agencies, and international cooperation agencies.

Showing the local reality, as well as the ways to face deficiencies, is a collective responsibility. However, planting solutions and spreading them is the responsibility of the central actors since they are the interlocutors of the local reality. Collective, integrative work, without exclusion, will enable a better adaptation of the indigenous peoples in Brazil, an aspect that must be widely promoted and debated.

5 CONCLUSIONS

Through the SNA, we observed the people's means of exchanging internal and external information regarding the impacts of climate change, as well as the existing social and institutional bottlenecks, which, together with adequate planning, could enable the implementation of more adaptive measures.

The identification and detailed understanding of socio-environmental issues and the dynamics of interaction and flow of information among the people made it possible to find the most recommended means for implementing adaptive measures. At the same time, we observe that the interconnectivity of levels becomes an essential factor in obtaining better and lasting results, encouraging future researchers and cooperation agencies to use this approach.

A successful example of an integral and multiscale analysis in the Tuxá occurred in the creation of the school. There, the people, relying on their knowledge and cultural bases, supported by local and regional institutions and mediated by central indigenous representatives and actors, managed to create the indigenous school, encouraging community members to face discrimination, revive their culture and generate more human and legal resources to fight for their rights (BERNAL, 2021b).

Finally, it is hoped that the results of this analysis will shed light and valuable information, both for the Tuxá people and for decision-makers in public and private sectors in the implementation of adaptive measures. Likewise, it is expected that these will help generate spaces for organisation, operationalisation and cooperation between different individuals, seeking to facilitate processes for implementation.

ACKNOWLEDGMENTS

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A rede social indígena Tuxá, interação e troca de informação para a promoção de medidas adaptativas ante as mudanças climáticas

The Tuxá indigenous social network, interaction and exchange of information for the promotion of adaptive measures in the face of climate change

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ARTICLE- VARIA

RESUMO

Estudos mostram a Análise de Redes Sociais (ARS) como uma exitosa metodologia dentro das ciências ambientais. No presente estudo essa metodologia foi implementada na comunidade indígena Tuxás da Bahia – Brasil, com o intuito de compreender a configuração de interação e fluxo de informação do povo e sua relação multinível para enfrentar a problemática ambiental da seca. Identificamos mediante a realização de redes por escalas, atores e seus papéis dentro da comunidade, caracterizando a centralidade dos atores e as suas relações internas e externas para projetar a criação de ações estratégicas adaptativas que fortaleçam os vínculos entre eles e as iniciativas locais e regionais. Para a coleta de dados, foram realizadas entrevistas estruturadas a informantes-chaves usando a metodologia bola de neve. A ARS permitiu identificar elos, gargalos e potenciais instituições para diminuir a vulnerabilidade da população tradicional, assim como identificar caminhos adequados para promover adaptação e dar solução a problemáticas ambientais.

Palavras-chave: Análise de redes sociais. Povos indígenas. Adaptação. Vulnerabilidade. Medidas adaptativas.

ABSTRACT

Studies show Social Network Analysis (ARS) as a successful methodology within the environmental sciences. In the present study, this methodology was implemented in the Tuxás indigenous community in Bahia – Brazil, with the aim of understanding the configuration of interaction and information flow of the people and their multilevel relationship to face the environmental problem of drought. Through the creation of networks by scale, we identify actors and their roles within the community, characterizing the centrality of actors and their internal and external relationships to design the creation of adaptive

strategic actions that strengthen the links between them and local and regional initiatives. For data collection, structured interviews were conducted with key informants using the snowball methodology. The ARS made it possible to identify links, bottlenecks and potential institutions to reduce the vulnerability of the traditional population, as well as to identify adequate ways to promote adaptation and solve environmental problems.

Keyword: Social network analysis. Indigenous Peoples. Adaptation. Vulnerability. Adaptive measures.

INTRODUÇÃO

A realização de uma ARS possibilita descrever de forma quantitativa e qualitativa pontos importantes de fenômenos sociais ligados a outros temas específicos, como saúde, problemas ecossistêmicos, culturais, ambientais, entre outros (BERKHAM; GLASS, 2000; WASSERMAN; FAUST, 1994). O interesse por realizar esse tipo de análise tem crescido nos últimos anos em diversas áreas de pesquisa (FONTES; EICHNER, 2011; GOMIDE; SCHÜTZ, 2015; RIBEIRO; BASTOS, 2011).

Dentro das ciências ambientais e sociais, algumas pesquisas avaliam temas vinculados às mudanças climáticas e ao estabelecimento ou medição de mecanismos de adaptação, no entanto, estes são em sua maioria realizados fora do país e concentram sua atenção em dois aspectos: 1) Análises das redes institucionais existentes que abordam mudanças climáticas, seus impactos e os mecanismos de adaptação (BICKEL, 2017; CEDDIA, 2017; CORLEW, 2015; ISLAM, 2017; JAJA, 2016; JONES, 2014) e 2) Estudos de viabilidades de adaptação em comunidades locais específicas (ANDRÉ, 2017; CHAUDHURY, 2017; DONG, 2017; FARRELL, 2015; NOH, 2015; RECKIEN, 2012; SCHRAMSKI, 2016; ZIERVOGEL, 2017).

Neste artigo apresentamos como a análise de redes sociais pode contribuir para a implementação de medidas adaptativas na comunidade indígena Tuxá da Bahia – Brasil. Esse povo encontra-se espalhado em três estados do Brasil: Bahia, na Aldeia Mãe Rodelas e D'zorobabé, Fazenda Sítio, Terra Indígena, Ibotirama e Reserva Indígena Fazenda Remanso; Pernambuco, em Inajá/Fazenda Funil e Kambiwá Tuxá (divisa Pernambuco/Alagoas) e Minas Gerais, Buritizeiro. A sua dispersão é o resultado da construção da Usina Hidrelétrica Luiz Gonzaga em 1988, que, segundo os estudos realizados por Bernal e Rodrigues Filho (2020; 2021), gerou impactos socioambientais alarmantes sobre o grupo indígena, entre eles intensas mudanças no cotidiano, perda de identidade, migração, divisão, pobreza e, consequentemente, deficiência alimentar e hídrica, que, em razão da perda territorial e os impactos dos eventos extremos produzidos pelas mudanças climáticas, vem se intensificando.

Conhecendo essa situação, observou-se a necessidade de implementar medidas adaptativas para diminuir a vulnerabilidade da população. Nesse sentido, com a finalidade de identificar as principais vias para o seu estabelecimento, desenvolvemos três redes sociais, identificando, por um lado, os potenciais gargalos e, por outro, as vias que podem contribuir para a implementação das medidas adaptativas de maneira mais efetiva, lidando com a problemática Tuxá a partir de uma interconectividade escalonada. O estudo analisa quatro redes: a de troca de informação da seca do povo Tuxá, a rede de potenciais gargalos sociais, a rede de ligações sociais e institucionais para a adaptação e a de multiescalaridade adaptativa. Identificamos a densidade da rede de comunicação do povo e a centralidade dos indivíduos, resultados que serviram de base para analisar as relações de colaboração entre os envolvidos na pesquisa.

2 REVISÃO DA LITERATURA

2.1 A COMPLEMENTARIDADE DA ANÁLISE DE REDES SOCIAIS (ARS) E SUA APLICAÇÃO EM ESTUDOS DE VULNERABILIDADE E ADAPTAÇÃO

A ARS é uma metodologia utilizada há décadas em diferentes áreas do conhecimento. Permite identificar interações sociais e estudar redes existentes, sejam informais, espontâneas e não intencionais (GROSSETTI, 2003; 2004), assim também possibilita analisar a estrutura das ligações existentes entre os indivíduos em um contexto social determinado (TOMAEL; MARTELETO, 2013).

Pesquisas recentes afirmam que a ARS se torna um denominador comum para lidar efetivamente com problemas socioambientais (BODIN, 2009; BURGOS; MERTENS, 2017; VELÁZQUEZ *et al.*, 2005). Dentro das pesquisas que mostram como a aplicação contribui para a compreensão da vulnerabilidade social diante dos efeitos das mudanças climáticas, alguns realizam avaliações específicas sobre indivíduos e grupos sociais em relação à problemática, entretanto, outros analisam como as instituições, as políticas públicas implementadas, a confiança e a comunicação em redes são determinantes para praticar medidas de adaptação eficientes.

Kate *et al.* (2015), por exemplo, avaliam a natureza estrutural e a extensão de comunicação baseada no clima entre profissionais das Ilhas do Pacífico; os autores identificam os principais centros regionais e grupos isolados, com o objetivo de criar um conjunto de ferramentas baseadas em locais que aumentariam e facilitariam a conexão dos diferentes recursos das mudanças climáticas (humanos, econômicos, pesquisa e adaptação). Os resultados do estudo revelam uma rede simultaneamente difusa e fortemente conectada, sem grupos espaciais ou setoriais isolados.

No mesmo ano Matthew (2015) realiza uma crítica quanto ao uso ou interpretação da pobreza como indicadores de vulnerabilidade, porque as relações sociais, segundo ele, moldam a multidimensionalidade da vulnerabilidade. Analisando membros de 54 famílias na Nigéria, o autor exibe que a pobreza por si só é uma medida incompleta da vulnerabilidade de um indivíduo ou de um agregado familiar, devido não apenas à aleatoriedade do risco biofísico, mas também a diferentes obrigações e direitos associados à riqueza. A análise feita pelo autor mostra que mulheres e homens jovens tendem a ganhar mais riqueza em relação aos homens mais velhos, e os ganhos de mulheres saudáveis não refletem sua menor vulnerabilidade em comparação com os homens mais velhos, mas sim suas reações para abordar suas posições vulneráveis.

Estudando as zonas áridas e semiáridas da África do Norte e do Oriente Médio, Alary (2016) mostra a existência de um vínculo entre os meios de subsistência da família e o capital social da sociedade beduína e uma ligação importante entre ativos físicos, natureza, o nível de educação e a intensidade dos elos sociais dentro da sociedade tradicional. Este estudo apresenta particularidades semelhantes ao desenvolvido por Matthew (2015), em ambos, a vulnerabilidade de um indivíduo se dá devida não apenas à aleatoriedade do risco ou um fator particular, mas também à somatória de aspectos que torna o indivíduo e uma sociedade mais vulneráveis.

Analisando políticas de gestão de desastres e mudanças climáticas em Bangladesh, Islam e Walkerden (2017) avaliam as maneiras em que estas levam ou não em consideração as redes sociais das famílias. Este estudo mostra que apesar da importância das redes sociais na resiliência e recuperação de desastres, estas não recebem ênfase nas políticas governamentais, no entanto, as organizações que vinculam redes sociais (ou seja, links de governos com organizações de Estados, doadores e outros) sim. Sendo que as redes de vínculo familiar (relacionamentos com familiares e parentes imediatos), redes de ponte (relacionamentos das famílias com vizinhos e amigos) e seus relacionamentos locais de ligação (principalmente com Organizações Não Governamentais – ONGs e governo local) são amplamente ignorados.

Observa-se que surge a necessidade de incorporar estudos que perpassem essas análises escalares unitárias, como a incorporação de estudos multiníveis que mostrem claramente as conexões existentes dentro de uma sociedade particular e sua interação com outros setores e níveis da mesma sociedade, garantindo, por um lado, compreender as características sociais do grupo, e, por outro, chamando atenção de autoridades setoriais e governamentais, que, baseados em dados concretos, proponham planos, ações, projetos, medidas ou políticas concretas de acordo com a realidade e necessidades.

Por exemplo, Chaudhury *et al.* (2017), com o objetivo de examinar a conectividade e as posições de comunidades rurais vulneráveis, famílias e sua capacidade de adaptação em Gana, mostram que algumas relações externas expõem famílias à desinformação e ao desconhecimento, assim como a outras formas de capital, que, por sua vez, fortalecem sua capacidade de acessar e mobilizar recursos para responder às mudanças ambientais. Os autores manifestam que nem todas as relações externas têm acesso igual e que a capacidade de adaptação das famílias dentro da comunidade está estratificada.

Como pode ser observado neste estudo, os autores identificam pontos em que os atores locais podem vincular comunidades e famílias a agências cruciais de cooperação no intuito de planejar e implementar uma adaptação eficaz. A esse ponto referimo-nos quando uma análise multiescalar sobre o tema permitiria uma compreensão real sobre a sociedade Tuxá, sua vulnerabilidade e as possibilidades existentes para viabilizar sua adaptação. Existem alguns trabalhos que realizam esse tipo de análise. Ernstson (2008), por exemplo, considerando os padrões de interação entre organizações, revela que uma estrutura núcleo-periferia de organizações centrais e semicentrais pode construir conexões políticas com as autoridades, nas quais a periferia reúne todos os grupos de usuários envolvidos nas atividades cotidianas, facilitando processos de ação coletiva de proteção. Alguns anos mais tarde, Ernstson (2010) mostra também como agências governamentais e grupos da sociedade civil engajados na gestão da área urbana podem se conectar por meio de redes sociais para combinar escalas espaciais de processos ecossistêmicos.

Este último trabalho é um dos mais importantes dentro da análise multiescalar, já que, efetuando uma estrutura, une escalas ecológicas com estruturas de redes sociais, sendo estas últimas tomadas como padrões de interação entre grupos de atores. O artigo mostra que áreas verdes locais, funcionalmente interconectadas, não são abordadas por nenhum ator em Estocolmo e que as práticas de gestão de grupos da sociedade civil, implicados no manejo do ecossistema local, são cruciais, mas regularmente negligenciadas. Finalmente, Cash (2006), analisando a escala cruzada na gestão do meio ambiente, mostra que existe uma grande complexidade nas análises de interações, no entanto, afirma que a dinâmica das interações em escala cruzada e entre níveis é afetada pela interação entre instituições em múltiplos níveis e escalas.

3 METODOLOGIA DO ESTUDO E TRATAMENTO DOS DADOS

O estudo metodologicamente é de caráter qualitativo e baseia-se no protocolo de pesquisa da Sub-rede Mudanças Climáticas e Desenvolvimento Regional 2014 do Brasil e os procedimentos metodológicos para a realização da Análise de Redes Sociais (ARS). A Sub-rede Mudanças Climáticas e Desenvolvimento Regional da Rede Clima do Brasil possui um documento denominado protocolo de pesquisa, o qual é usado atualmente em pesquisas que incorporam análises das Mudanças Climáticas e seus impactos, permitindo a realização de avaliações socioambientais reconhecidas nacional e internacionalmente.

Os dados primários foram coletados mediante entrevistas estruturadas na comunidade indígena Tuxá, localizada na região semiárida do município de Rodelas-BA (ver Figura 1). Os dados foram coletados em duas visitas a campo: a primeira em outubro de 2017 e a segunda entre novembro e dezembro de 2018.

O número de entrevistas foi determinado mediante a metodologia bola de neve, permitindo chegar aos informantes mais destacados da comunidade, entre eles: lideranças, professores e representantes

indígenas, os quais mostraram ter conhecimentos sobre a história do povo, os impactos de eventos extremos e sobre as decisões estabelecidas na comunidade.

Ao todo, foram aplicadas 97 entrevistas estruturadas (68 em Rodelas e 29 em Surubabel) a homens e mulheres de diferentes grupos, com a finalidade de compreender como esse grupo social interage interna e externamente no contexto de temas e conhecimentos sobre impactos das secas provocadas pelas mudanças climáticas. As redes apresentadas no estudo são o resultado de perguntas concretas, que, devidamente consolidadas numa base de dados, foram processadas nos *softwares* Ucinet e NetDraw.

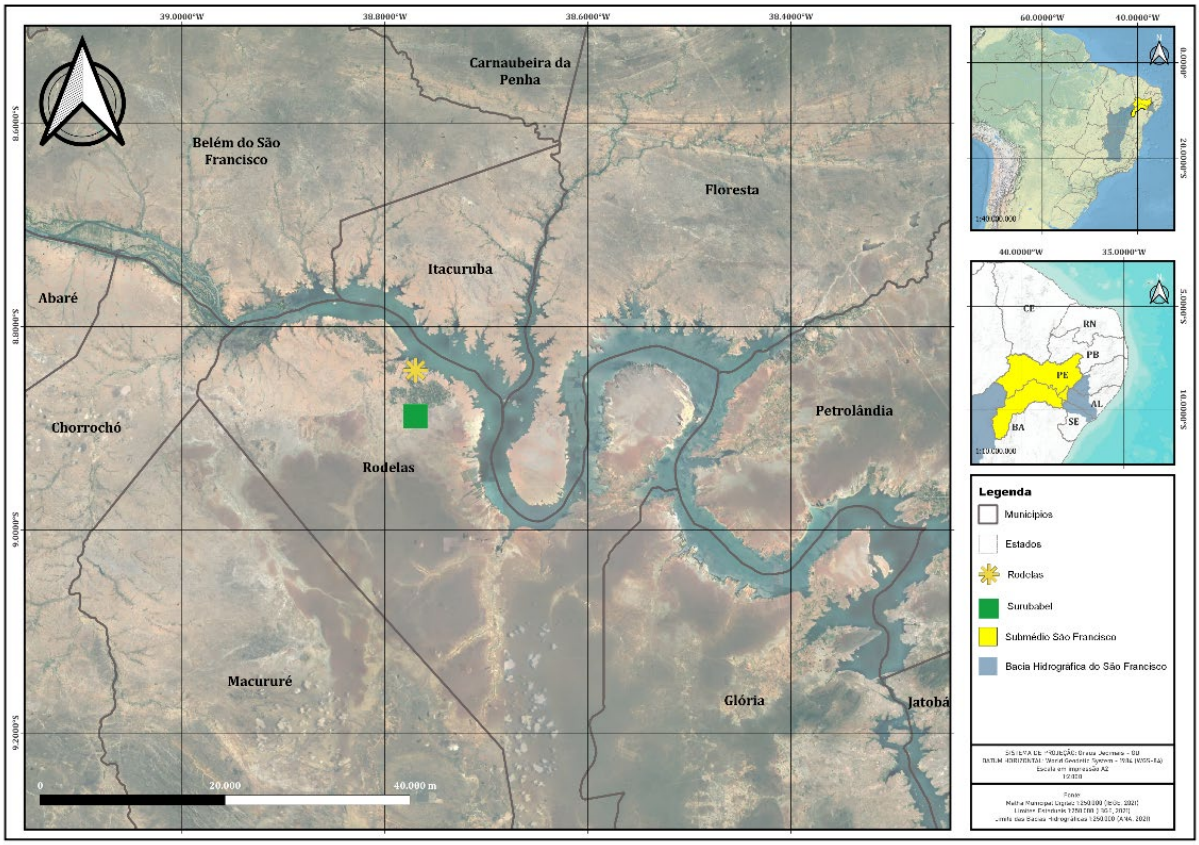

Figura 1 | Áreas de coleta de dados primários da Pesquisa

Fonte: Elaboração própria

Por fim, note-se que este estudo atende às normas e exigências do Comitê de Ética em Pesquisa da Faculdade de Ciências Humanas e Sociais da Universidade de Brasília (UnB), processo devidamente registrado no protocolo Nº 01037218.5.0000.5540 e aprovação Nº 3.440.

4 RESULTADOS

4.1 A REDE DE TROCA DE INFORMAÇÃO DE SECA DOS TUXÁ DE RODELAS

Elaborando e analisando a primeira rede exposta na Figura 2, adverte-se que comumente membros do povo indígena costumam conversar sobre a seca e suas consequências, principalmente com a população que possui um grau de representatividade, liderança e confiança (ver Figura 2). Uma importante proporção da população tende a dialogar especificamente com cinco indivíduos, que possuem um grau de centralidade importante dentro do povo, fato que permite notar um caminho adequado para

viabilizar maior comunicação, já que o envolvimento destes com a população, sua representatividade e facilidade de aproximação com um número importante de pessoas possibilitariam uma melhor implementação de atividades ou medidas adaptativas locais.

Essa rede possui uma densidade de 0,2, que, ao contrário de apresentar uma saturação por inter-relações, é adequada, já que densidades muito altas podem levar à homogeneização e redundância de conhecimentos reduzindo a eficácia da ação coletiva e a capacidade de adaptação (BODIN, 2006; BURGOS, 2014). As ligações existentes mostram uma conexão importante entre determinados indivíduos, o que nos ajuda a ver quais são os mais representativos.

Para promover medidas adaptativas ou implementar políticas públicas dentro da comunidade indígena, pode-se buscar incrementar a densidade da rede de maneira gradual mediante a promoção de diálogo entre a população local, fato que contribuiria para que as ações realizadas na comunidade sejam maiormente eficientes.

A segunda rede identifica as pessoas ativas dentro da comunidade com uma aproximação efetiva com instituições. Observamos que são cinco indivíduos os mais citados, constituindo-se estes nos mais representativos e, por sua vez, estratégicos para impulsionar algumas atividades, já que mediante essa análise pode-se identificar o grau de importância que cada ator possui, sua posição dentro da comunidade em relação à intercomunicação, prestígio e representatividade, no intuito de identificar a influência que cada um tem sobre a população e em âmbito institucional.

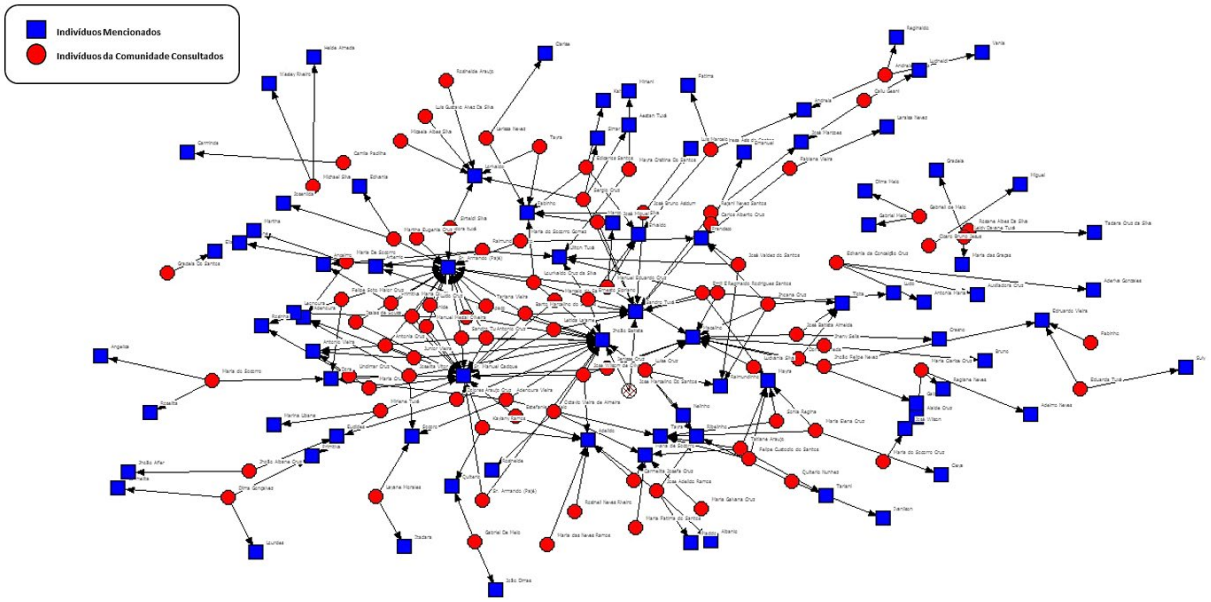

Figura 2 | Rede de troca de informação sobre seca

Fonte: Elaboração própria

Observando a Figura 3, vemos uma divisão na percepção da população sobre representatividade dos atores. Alguns alegam que os representantes mais idosos da comunidade são os que mais têm contato com diferentes instituições, no entanto, outros grupos afirmam que jovens ativos são os que mais interagem. Essa percepção deve-se fundamentalmente a dois fatores: a idade das pessoas consultadas e o papel dos indivíduos.

Em respeito ao primeiro ponto, identificou-se que as pessoas acima de 40 anos, na sua maioria, identificam o Sr. Armando e Manuel como os atores que interagem mais com instituições, no entanto, para as pessoas mais jovens são Sandro Tuxá, Antônio Fernandez (Dinamam) e Uilton Tuxá. Em relação

aos representantes mais idosos da comunidade, observa-se que quem indica o Sr. Manuel (Cacique Bidu) como articulador com diferentes instituições são principalmente donas de casa, aposentados e funcionários públicos de maior idade, observando aqui que a representatividade se dá por geração. Em relação ao segundo fator, observa-se que Dinamam é indicado principalmente por funcionários públicos, estudantes e agricultores, e Sandro Tuxá por funcionários públicos, pescadores e aposentados da comunidade, fato que se fundamenta pela função ativa *in situ*.

A rede permite identificar as principais pessoas que mantêm uma aproximação significativa com instituições, como também suas relações dentro da comunidade, que, transmitida à população, permitiria gerar uma maior confiança e desencorajar aquelas outras isoladas, com o objetivo de aproximar atores pouco representativos aos indicados majoritariamente. Por outro lado, observam-se os caminhos mais adequados para a implementação de medidas adaptativas, políticas públicas ou projetos dentro da comunidade indígena.

Uma aproximação adequada e a realização de atividades focadas por grupos e dirigidas por atores sociais de maior representatividade possibilitariam obter os resultados esperados da melhor maneira. Iniciar atividades só com lideranças não garante êxito nas atividades impulsionadas, já que fatores pessoais da liderança e os atores adjacentes também se tornam determinantes, porque em muitos casos projetos e políticas bem-sucedidos são resultantes da geração de ações, transmissão de informação, empatia, coordenação e mediação, possibilitando a assimilação de ações, procedimentos e informação.

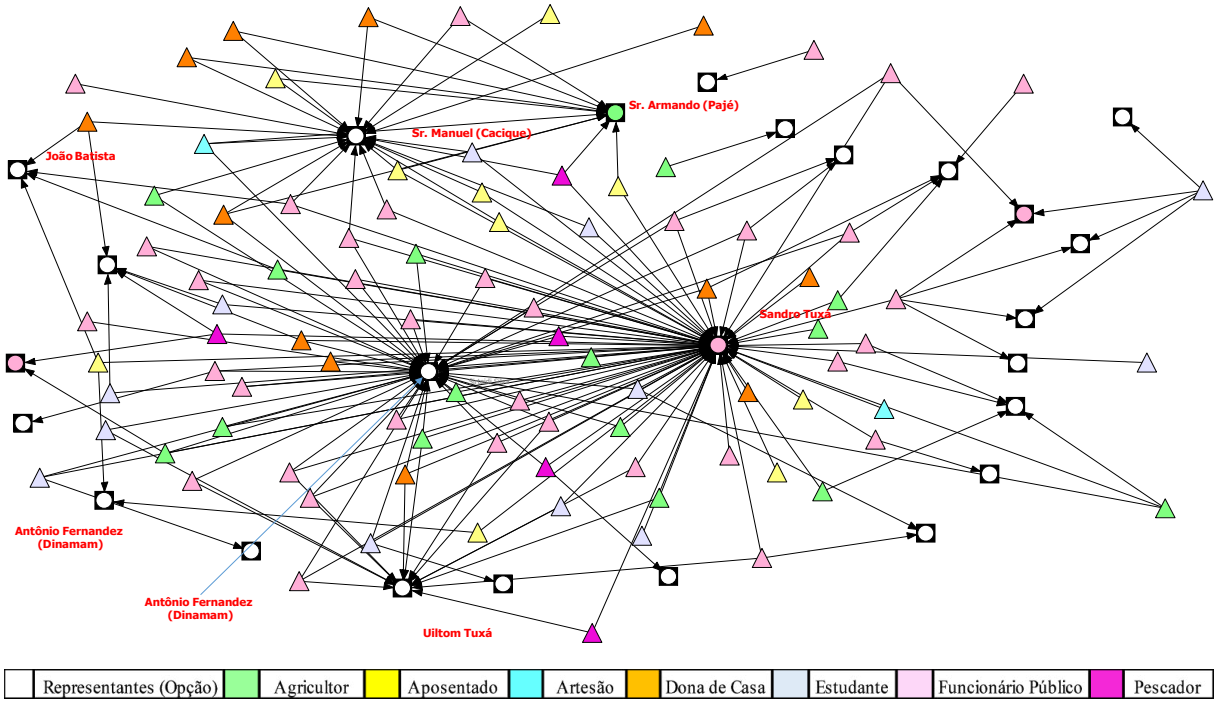

Figura 3 | Rede de representantes indígenas ante instituições públicas e privadas

Fonte: Elaboração própria

4.2 A IMPORTÂNCIA DAS INSTITUIÇÕES PARA ENFRENTAR AS MUDANÇAS CLIMÁTICAS EM RODELAS

O fortalecimento e a criação de instituições na avaliação e implementação de medidas adaptativas para reduzir a exposição e sensibilidade da população vulnerável tornam-se um fator determinante (IPCC, 2014). No Brasil, nos últimos 20 anos, o Fundo Amazônia, recentemente reativado e financiado por doações de diversos governos, assim como projetos de instituições multilaterais, Organizações Não

Governamentais (ONGs), empresas e instituições públicas, ajudaram a gerar políticas de mitigação às mudanças climáticas.

Os avanços em temas, como acesso à água, alimento, geração de renda, agricultura, entre outros, diminuíram a pobreza existente em algumas regiões do país, assim como a exposição e sensibilidade da população carente às mudanças climáticas. No entanto, o desenvolvimento de projetos e de políticas de adaptação ainda é deficiente. Rodrigues Filho (2016) afirma que a atuação brasileira ante as mudanças climáticas se desenvolveu de forma político-institucional e legislativa, majoritariamente com foco nas ações voltadas para a mitigação, deixando a adaptação num espaço marginal. Nesse sentido, sendo o Brasil um dos países que apresentam uma elevada vulnerabilidade, torna-se urgente incluir esse ponto de forma efetiva na agenda nacional e institucional (LINDOSO, 2013). Portanto, é indispensável um esforço continuado e um enfoque global orientado a identificar estratégias, políticas e instrumentos que permitam o fortalecimento de instituições e o desenvolvimento de medidas efetivas para enfrentar os impactos das mudanças climáticas.

Compreendida a situação de vulnerabilidade do povo indígena Tuxá (BERNAL, 2021a; 2021b), e com a finalidade de identificar possíveis gestores para a implementação de medidas adaptativas por meio do relato da população, verificou-se a existência de 29 instituições que ao longo dos últimos 15 anos apoiaram o povo com diversas iniciativas socioambientais (Tabela 1), entre elas projetos de melhoria de renda e acesso à água, assim como desenvolvimento de capacidades locais e combate à seca.

Entre as atividades para enfrentar a seca, afirma-se que se promoveu a construção de açudes e barragens, aquisição de sementes e animais para a promoção da agricultura e pecuária, fortalecimento para o desenvolvimento da piscicultura indígena, perfuração de poços e ações mais diretas da população, como assistência para distribuição de alimentos, fortalecimento da saúde pública, criação de fontes de trabalho alternativo, entre outras.

Lideranças da comunidade indicam que muitos dos projetos realizados geraram resultados positivos durante a sua implementação, no entanto, afirmam que uma vez deixados de ser monitorados pelas instituições, os projetos e resultados foram decaindo. Porém, manifestam que os benefícios foram positivos, já que sem estes os impactos da última seca registrada entre 2014 – 2018 teriam provocado perdas maiores para a população local.

Tabela 1 | Instituições que apoiam o povo Tuxá no enfrentamento da seca

Sigla	*Nome da Instituição*	*Sigla*	*Nome da Instituição*
Agendha	Assessoria e Gestão em Estudos da Natureza, Desenvolvimento Humano e Agroecologia	Funasa	Fundação Nacional de Saúde
ANA	Agência Nacional de Águas	GOBERNO ESTADUAL	Governo estadual
Anai	Associação Nacional de Ação Indigenista	Iica	Instituto Interamericano de Cooperação para a Agricultura
Apoime	Articulação dos Povos e Organizações Indígenas do NE, MG e ES	Insa	Instituto Nacional do Semiárido
ASA	Articulação Semiárido Brasileiro	MDA	Programa de Meio Ambiente do Ministério do Desenvolvimento Agrário
Bahia Pesca	Bahia Pesca Governo da Bahia	MMA	Ministério do Meio Ambiente
CAR	Companhia de Desenvolvimento e Ação Regional	Mopoiba	Movimento Unido dos Povos e Organizações Indígenas da Bahia
CBHSF	Comitê da Bacia do Rio São Francisco	Cojipe	Comissão de Juventude Indígena de Pernambuco
CX	Centro Xingó	PR	Prefeitura de Rodelas
Chesf	Companhia Hidrelétrica do São Francisco	Secretaria de Educação	Secretaria de Educação

Sigla	Nome da Instituição	Sigla	Nome da Instituição
Codevasf	Companhia de Desenvolvimento dos Vales do São Francisco e do Parnaíba	Sesai	Secretaria Especial de Saúde Indígena
Cras	Centro de Referência da Assistência Social	SPI	Serviço de Proteção aos Índios
E I R	Escola Índígena de Rodelas	UFBA	Universidade Federal da Bahia
Funai	Fundação Nacional do Índio	UNB	Universidade de Brasília
Uneb		Universidade do Estado da Bahia	

Fonte: Elaboração própria.

Aplicada a ARS e conforme a percepção do povo Tuxá, as instituições que mais apoiam a população são: a Funai, a Escola indígena de Rodelas, a Sesai, a prefeitura de Rodelas, a CBHSF e as organizações Anai, Apoime e Agendha, instituições que, segundo manifestam, tornaram-se chaves para enfrentar as dificuldades provocadas pelas mudanças climáticas (Figura 4). Por exemplo, indicam que a escola indígena, a Funai e a Sesai apoiam o fortalecimento de capacidades, melhoramento sanitário e distribuição de alimentos, componentes considerados essenciais para gerar uma melhor adaptação e convivência com a seca. Já o CBHSF e a Agência Agendha, realizaram projetos de disponibilidade hídrica ajudando-o a enfrentar a problemática da seca.

Uma efetiva implementação das linhas estratégicas propostas para adaptação e mitigação requer a consolidação de políticas públicas e um adequado labor entre atores sociais e instituições. As características humanas, potencialidades e conhecimentos dos indivíduos envolvidos tornam-se desnecessários se as organizações e instituições não os valorizam e nem os promovem para planejar projetos ou medidas adaptativas.

Nesse sentido, vemos como é importante considerar cada sugestão e conhecimentos da população local no momento de plantear e gerar políticas focalizadas. Alary (2016), Chaudhury *et al.*, (2017), Islam e Walkerden (2017) afirmam que a compreensão dos aspectos culturais e saberes da população tradicional, somada a uma adequada vinculação a apoios de organizações, governos e doadores, permite o desenho adequado de políticas e projetos de adaptação, garantindo ótimos resultados no momento da sua aplicação.

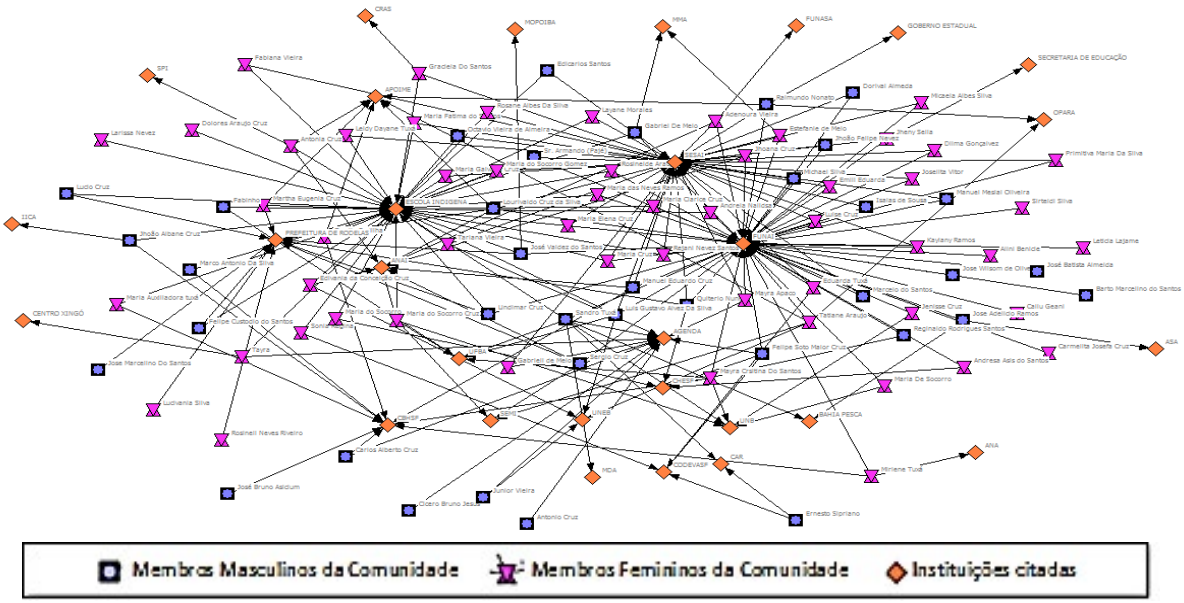

Figura 4 | Identificação das instituições que vêm apoiando a população Tuxá no combate à seca

Fonte: Elaboração própria

Esses aspectos apresentados chamamos como uma nova forma de institucionalidade não compartilhada e de coordenação horizontal e integração das capacidades técnicas. A rede exposta na Figura 4 permite ver as vias institucionais que ajudariam a enfrentar da melhor maneira os impactos da seca sobre o território indígena, em que a estrutura institucional vinculada às ações coletivas da população torna-se eficaz para garantir a coordenação e uma adequada integração para diminuir a vulnerabilidade. Portanto, o envolvimento de um maior número de instituições e atores sociais pode levar à obtenção de melhores resultados, assim como a um adequado e eficaz planejamento e implementação de adaptação dentro da comunidade (CHAUDHURY *et al.*, 2017).

4.3 MULTIESCALARIDADE ADAPTATIVA E INTERCONECTIVIDADE DE REDES PARA GARANTIR A ADAPTAÇÃO TUXÁ

Segundo Engle (2011) e outros autores, as determinantes para conseguir uma adequada capacidade adaptativa estabelecidas pelo IPCC (2007) incluem o envolvimento de recursos econômicos, tecnologia, informação, infraestrutura e instituições (SMIT; WANDEL, 2006). Em estudos Sociológicos, de Economia Política e Geografia, a capacidade adaptativa está relacionada à habilidade de agir coletivamente, em que o capital social, confiança e a organização são importantes (ENGLE, 2011; LEMOS, 2016; PELLING; HIGH, 2005).

Nesse sentido, a geração de capacidade adaptativa depende da disponibilidade de infraestrutura, recursos econômicos e tecnológicos, assim como de fatores sociais, como capital social, coordenação, fluxos de informação, confiança, predisposição de aprendizado e transmissão de conhecimentos (EAKIN; LEMOS, 2006). Para diminuir a vulnerabilidade da população indígena Tuxá, identificaram-se algumas tecnologias sociais como medidas de adaptação para a população (Tabela 2), no entanto, analisando o contexto social e as redes estabelecidas até aqui, considera-se que devem ser implantadas por meio da multiescalaridade e a interconectividade.

A maneira tradicional de conceber a ciência muitas vezes fez com que problemáticas sociais e ambientais fossem estudadas de maneira fragmentada. Porém, em análises de conservação e do aproveitamento dos recursos naturais nas ciências ambientais, permitiu associar essas problemáticas e analisá-las de maneira diferenciada, possibilitando compreendê-las melhor (MONTAÑEZ, 2005). Esses novos processos de análise deram início ao conceito "*multiescalar*", com diferentes níveis de participação e complexidade, entre eles aspectos geográficos, sociais, políticos e ecossistêmicos, que ingressam numa análise conjunta, compreendendo contextos, realidades e especificidades locais (CASH, 2006).

Abordagens analíticas "multiescalares" são particularmente apropriadas para compreender esta relação entre homem, mobilidade populacional, meio ambiente, uso da terra, geração de políticas públicas, entre outros, em diferentes, porém interconectadas escalas e níveis de análise espaciais e temporais (BARBIERI, 2007; CASH, 2006). O processo da dinâmica social, sobretudo na multiescalaridade, é considerado a partir de pelo menos três elementos: a flexibilidade, a descontinuidade e a superposição (COELHO, 2013). Outro aspecto relevante da multiescalaridade desde uma perspectiva mais social é a centralidade da noção de poder, cujas complexas relações de poder, entre os mais variados agentes que operam em múltiplas escalas, permitem analisar a multiescalaridade do território, uma sociedade, políticas públicas e a interação de atores em que o poder se manifesta e se exerce (COELHO, 2013).

Realizando uma análise da multiescalaridade aplicada à avaliação das diferentes redes elaboradas até aqui, observamos na rede de troca de informação do povo Tuxá sobre a seca que a população indígena, preferencialmente, tende a conversar sobre o assunto com cinco atores centrais da comunidade que, por sua vez, são representantes da comunidade e dedicam-se a diferentes atividades econômicas. No entanto, concentram informações, conhecimentos sobre a realidade indígena, assim como confiança e poder sobre o resto da população, fatores que podem ser aproveitados no momento da implementação das medidas adaptativas propostas.

Tabela 2 | Medidas de adaptação propostas

Sistema	*Descrição*	*Fonte*	*Instituições Guias*	*Referências*
Recuperação de Nascentes	Recuperar ou proteger uma área de nascente, além de ser um investimento ambiental, ajuda a garantir o fornecimento de água no campo e manter a biodiversidade local.	Tecnologia disponível no mercado	Centro Xingó	Gualdani et al. (2015)
Melhoramento genético vegetal	Melhoramento genético de culturas de sequeiro para a região semiárida, utilizado em sistemas de produção familiar, visando à obtenção de materiais vegetais tolerantes à seca e a elevadas temperaturas.	Pesquisa e desenvolvimento	Embrapa Semiárido, IPA	Costa et al. (2005); Santos et al. (2008)
Poço Cacimbão	Poço escavado de pequena profundidade que explora água proveniente do lençol freático para o fornecimento de água para animais e irrigação.	Tecnologia disponível no mercado	Centro Xingó	Gualdani et al. (2015)
Seleção de estirpes de rizóbio para leguminosas	Seleção e recomendação de estirpes de rizóbios autóctones do semiárido para a inoculação de feijão-caupi cultivado nessa região.	Tecnologia disponível no mercado	Embrapa Semiárido, Embrapa Agrobiologia e Uneb	Martins et al. (2003)
Ecofogão	Modelo mais eficiente que diminui o consumo de madeira entre 40% a 50%. Economia de lenha e diminuição de emissão de fumaça. Por ser fechado, não emite fumaça nem fuligem no ambiente onde estiver instalado, o que deixará o ambiente higiênico, limpo e saudável para as famílias.	Tecnologias transferidas	Centro Xingó	Gualdani et al. (2015)
Sistemas de captação de água *in situ*.	Tecnologias de captação de água da chuva: barragens subterrâneas, cisternas e barreiros de salvação	Tecnologias transferidas	Embrapa Semiárido, IRPAA	Brito et al. (2008); Lopes e Brito (1998)
Biodigestor	Equipamento que produz biogás e biofertilizante, por meio da utilização de fezes frescas de animais e água, em temperatura ambiente (20°C a 45°C). Produção de biogás e biofertilizante (adubo), reduzindo o consumo com gás de cozinha de maneira sustentável.	Tecnologias transferidas	Centro Xingó	Gualdani et al. (2015)
Construção de viveiros: piscicultura familiar.	Melhoria do manejo produtivo da piscicultura indígena.	Tecnologias transferidas	Embrapa Pesca e Aquicultura	Lima, A.; Prysthon, A.; Guedes, C.; Bergamin, G.; Pedroza, M. (2012)

Fonte: Elaboração dos autores com dados de Angelotti (2011) e Gualdani et al. (2015)

Esses indivíduos, ao possuírem confiança depositada, maior grau de centralidade (que significa também maior vinculação com outros atores), ajudariam na difusão de informação das medidas adaptativas adotadas, assim como em sua melhor implementação. No entanto, para isso, deve ser promovida uma interligação e comunicação ampla entre esses atores centrais e os atores que interagem entre a população e as instituições que implementam projetos em Rodelas, observados na Figura 3.

Nessa rede de vinculação de representantes indígenas ante instituições públicas e privadas, observamos que três indivíduos, principalmente, têm maior contato com instituições e representam grupos divididos por gerações e atividades econômicas. Tanto Sandro como o Sr. Manuel formam parte da rede de troca

de informação do povo indígena, se constituindo como atores-chaves e interlocutores entre a sociedade indígena e as instituições, já que também formam parte da segunda rede. Porém, observamos que é preciso estabelecer uma articulação efetiva entre esses indivíduos e Dinamam Tuxá, posicionado no nível da representatividade indígena diante das instituições com alto grau de centralidade (Figura 3). Esse fator promoverá de maneira mais efetiva um escalamento adequado ante as instituições, pois o mencionado ator exerce uma forte representatividade dos povos indígenas na região e no Brasil.

O estabelecimento da interconectividade é outro fator determinante para o bom estabelecimento das iniciativas. Observando possíveis conexões entre os diversos indivíduos da comunidade, atores centrais do (primeiro nível), interlocutores dos grupos com instituições (segundo nível) e instituições ativas sobre a região (terceiro nível), e promovida uma adequada sincronicidade no momento de planejar e implementar medidas adaptativas para os Tuxás, a efetivação das conexões permitiria advertir resultados efetivos e duradouros, que não só se concretizem no curto prazo, e sim se estabeleçam como projetos sólidos de longo prazo (Figura 5).

Comumente, os projetos implementados em diferentes contextos tendem a perder força assim que os promotores saem. Esse tipo de implementação que prioriza a interconectividade e o escalamento de interações sobre problemáticas e soluções determinadas visa garantir o bom sucesso das iniciativas implementadas, assim como gerar sua sustentabilidade, devido a que tanto as necessidades como as possíveis soluções surgem da população, fazendo com que sua análise vinculante, envolvendo indivíduos estratégicos desde o início até a consolidação das iniciativas, consolide um pertencimento do realizado, levando a que ações, iniciativas e conhecimentos transmitidos para a população permaneçam.

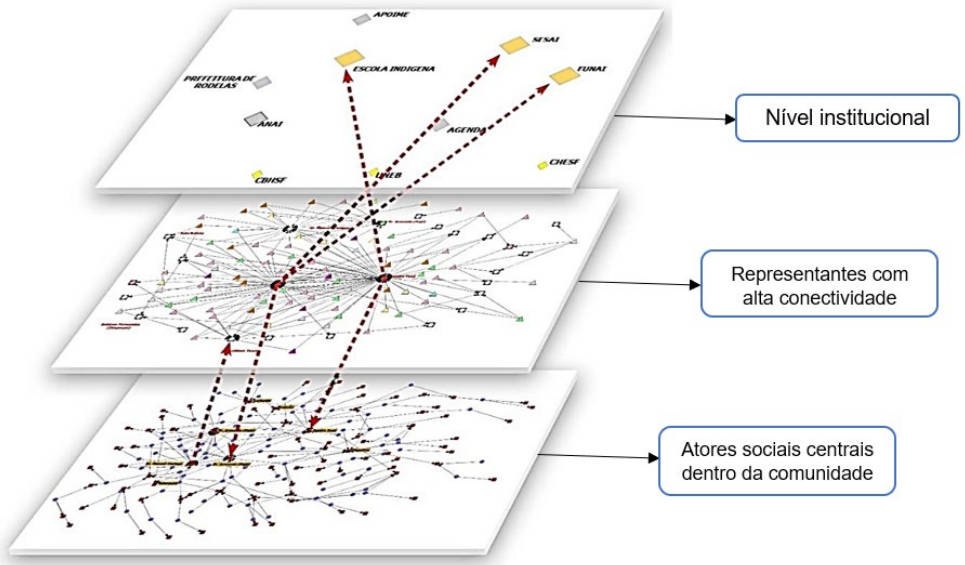

Figura 5 | Sistema de interconectividade dos atores sociais e instituições. Multiescalaridade para a implementação de medidas adaptativas

Fonte: Elaboração própria

Até aqui observou-se que a ARS possibilita identificar elos ou gargalos e potenciais instituições para diminuir a vulnerabilidade do povo indígena, comprovando que uma análise integral e multiescalar ajuda na identificação desses aspectos, bem como propor os caminhos mais adequados. Mostrou-se que essa abordagem permite, a partir da coleta de dados empíricos sobre relações externas com atores locais independentes, criar capacidade adaptativa dificilmente gerada isoladamente, mas sim a partir da identificação de demandas, conhecimentos das famílias das ações de agências remotas, atenuando os riscos que provocam os impactos das mudanças climáticas.

Nesse cenário, os atores centrais e lideranças indígenas têm um papel essencial, e essa situação recorrente do cotidiano dos indivíduos exige deles e do grupo restante reorganização em prol da adaptação. No entanto, os indígenas representantes e centrais devem buscar financiamento em instituições, agências locais, privadas e públicas, bem como em agências de cooperação internacionais.

Mostrar a realidade local, assim como as vias para enfrentar as deficiências, é uma responsabilidade comum, no entanto, plantar soluções e difundi-las é responsabilidade dos atores centrais, já que estes levam as realidades e as preocupações do grupo indígena por meio da interlocução. Um trabalho coletivo, integrador e sem menosprezo permitirá obter uma melhor adaptação dos povos indígenas do Brasil, aspecto que deve ser amplamente promovido e debatido.

5 CONCLUSÕES

Observamos, mediante a ARS, os meios de troca de informação interna e externa do povo no quesito dos impactos das mudanças climáticas, assim como os gargalos existentes, tanto sociais como institucionais, que conforme a realização de um planejamento prévio e promoção adequada das medidas adaptativas propostas, sua implementação poderia se tornar mais viável. O tecido social Tuxá possui particularidades interessantes, que adequadas às necessidades do povo e realidade local, em relação à gestão de agências públicas e privadas, uma apropriada implementação de medidas adaptativas pode ser estabelecida.

A identificação e compreensão detalhada das problemáticas socioambientais e da dinâmica de interação e fluxo de informação do povo possibilitaram encontrar os meios mais recomendados, em que a problemática da segurança alimentar e hídrica dos Tuxás pode ser enfrentada mediante a implementação de medidas adaptativas, porém, por meio da sincronicidade entre os diferentes níveis no momento do planejamento e estabelecimento. Paralelamente, observamos que a interconectividade se torna um fator essencial para obter melhores e duradouros resultados, alentando futuros pesquisadores e agências de cooperação a abordarem esse enfoque.

Um exemplo de êxito de uma análise integral e multiescalar nos Tuxá deu-se na criação da escola e a promoção de uma educação contextualizada. O povo confiado nos seus conhecimentos e bases culturais, apoiado por instituições locais e regionais e intermediado por representantes e atores indígenas centrais, conseguiu criar uma escola indígena, encorajando os membros da comunidade a enfrentarem a discriminação, reavivar a sua cultura e gerar mais recursos humanos e jurídicos para lutar pelos seus direitos (BERNAL, 2021b).

Por fim, espera-se que os resultados desta análise permitam trazer luz e informações valiosas, tanto para o povo Tuxá como para tomadores de decisão do setor público e privado na implementação de medidas adaptativas. Assim também, espera-se que estes ajudem a gerar espaços de organização, operacionalização e cooperação entre diferentes indivíduos, na busca de facilitar processos para a implementação.

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In this third and final edition of 2022, Sustainability in Debate, in its editorial, discusses the lessons and warnings since the Montreal Protocol, of 1987, to the recent Loss and Damage Fund adopted at the United Nations Conference on Climate Change (COP-27).

Next, SiD publishes this year's peer-reviewers list and nine articles in the *Varia* section.

Ramos Junior *et al.* evaluate whether wind energy in Brazil has contributed to achieving goals assumed in the Paris Agreement. Soares & Barreto assess the political arena surrounding the issue of regulating the distributed generation of electricity in Brazil. Then, González examines the relationships between the energy transition, society and the environment, focusing on the use of copper. Ventura *et al.* evaluate the environmental benefits of implementing an urban mobility plan in Rio de Janeiro. Onofre *et al.* analyse how the Pontal do Paraná Industrial Port Complex projects evaluated the cumulative impacts. Ferrer *et al.* demonstrated the existence of unequal access to water in the different regions of a municipality in the state of São Paulo. Mendonça & Laques focus on a conceptual impact assessment model, presenting a theoretical model applicable to research and innovation organisations. Finally, Mendes *et al.* discuss specific vulnerabilities, adaptive measures and opportunities identified in three population groups in the Northeast, and Dávalos and Rodrigues-Filho analyse the use of Social Network Analysis (SNA) in an indigenous community in Bahia.

Nessa terceira e última edição de 2022, Sustainability in Debate*, em seu editorial, discorre sobre as lições e advertências dadas desde o Protocolo de Montreal, de 1987, ao recente Acordo de Perdas e Danos Climáticos, assinado na Conferência das Nações Unidas sobre Mudança Climática (COP-27).*

Na sequência, SiD publica a lista de pareceristas do ano e nove artigos na seção Varia*.*

Ramos Júnior et al. *avaliam se a energia eólica no Brasil vem contribuindo para o cumprimento de metas assumidas no Acordo de Paris. Soares & Barreto avaliam a arena política em torno do tema de regulamentação da geração distribuída de energia elétrica no Brasil. González examina as relações entre a transição energética, a sociedade e o meio ambiente, focando no uso do cobre. Ventura* et al. *avaliam os benefícios ambientais relacionados à implementação de um plano de mobilidade urbana no Rio de Janeiro. Onofre* et al. *analisam como os projetos do Complexo Industrial Portuário Pontal do Paraná avaliaram os impactos cumulativos. Ferrer* et al. *demonstraram a existência de um acesso desigual de água entre as diferentes regiões de um município no estado de São Paulo. Mendonça & Laques focam em um modelo conceitual de avaliação de impacto, apresentando um modelo teórico aplicável a organizações de pesquisa e inovação. Mendes* et al. *discorrem sobre as vulnerabilidades específicas, medidas adaptativas e oportunidades identificadas em três grupos populacionais do Nordeste, E, Dávalos e Rodrigues-Filho analisam o uso da Análise de Redes Sociais (ARS) em uma comunidade indígena da Bahia.*

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