SUSTAINABILITY IN DEBATE

SUSTENTABILIDADE EM DEBATE

EDITORIAL

ARTICLES VARIA

VOL. 12 - N. 2
MAY - AUG
2021
ISSN-e 2179-9067

Publisher Address: Campus Universitário Darcy Ribeiro - Gleba A, Bloco C - Av. L3 Norte, Asa Norte - Brasília-DF, CEP: 70.904-970

Phones: 55(61) 3107-6000, 3107-6001, 3107-6002, Fax: 3107-5972

E-mail: sustentabilidade.debate@gmail.com | Site: www.cds.unb.br
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Sustainability in Debate – Centro de Desenvolvimento Sustentável da Universidade de Brasília, v. 12, n.2 (2010 - 2021), Brasília, DF, Brasil.

Quarterly - ISSN Eletrônico 2179-9067

Desenvolvimento Sustentável. Universidade de Brasília. Centro de Desenvolvimento Sustentável.

CDU 304:577

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Editorial

Facing not-so-natural disasters

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

doi:10.18472/SustDeb.v12n2.2021.39361

Climatology is one of the most advanced scientific areas in recent decades. The confluence of factors related to scientific and technological evolution can explain it. Satellite technology has allowed a remarkable increase in data availability and accuracy. Besides, computer science has made possible the evolution of increasingly complex, consistent and capable of treating large databases models, both qualitatively and quantitatively. The results have been more reliable day after day, permitting scenarios' reproduction and discovering trends for more informed decision making. Proof of this advance is a recent article written by Tellman *et al*., (2021). The manuscript presents available data from flooded areas between 2000-2018 (with a resolution of 250m), identifying an affected area of 2.23 million km2 and 255 to 290 million people directly impacted by these events worldwide. It represents an increase of 58 to 86 million people between 2000 and 2015, number ten times higher than estimated by other studies. The Global Flood Database[1] created by these researchers should help identify, among several impacts, the most vulnerable areas and those with a greater need for adaptative measures, especially concerning climate change.

Despite these remarkable advances, recognized/famous climate scientists admit that it has not been possible to predict all recent extreme events, even in countries with a political and scientific commitment to preserving the environment and the fight against climate change, such as Germany. Even with science giving several warnings over decades that rapid global warming would bring worse episodes of rain and more intense heat waves, the tools we have are still not powerful enough to accurately project the level of gravity, the exact moment and the location of the manifestation of these extremes.

Nevertheless, models that point out disasters with accuracy are not enough to prevent them. It is essential to implement planning policies, comply with recommendations and invest in disaster prevention, besides relocating people and facilities outside risk areas.

Some recent examples of extremes events in the world are the floods in Europe and China, forest fires in the United States, Greece and Turkey, extreme heatwaves in Canada or even Siberia, water deficit in Brazil, including a new energy crisis in the middle of the Covid-19 pandemic, extreme weather events in Australia and Africa. Although impacts of climate change occur to a greater extent in the most socioeconomically vulnerable regions, events in Germany and Canada demonstrate that climate disasters can be democratic and equally lethal worldwide.

Prevention costs would be smaller than not investing in it and believing disasters will not occur since this may cause losses with a much higher economic value of remediation. Affected people from these regions make it clear that disasters in smaller magnitudes have already occurred. However, the authorities did not pay due attention. The iteration of these events with an increase in their extent expresses the lack of political decision-making.

Confronting these natural(ish) disasters requires computers for forecasting weather and climate change. Computer science supports the development of climate science. Even if the costs are high for better and larger computers and research support, they are negligible compared to material, economic and human losses associated with extreme events our societies are not ready to face.

Research still needs to evolve to predict the locations, moments, intensity and cyclical recurrence of countries facing extreme events such as heatwaves or floods. Thus, more sophisticated data and models are needed.

Investing in new computers and research that fills information gaps is not the only answer. There is a lack of action, not only politics! There is a need for collective and creative intelligence adapted to the generation of real-time solutions. Networks of inter- and transdisciplinary researchers (with one foot in academia and the other in the social, private or governmental spheres) should continue to generate knowledge that inspires actions and transformations through collaboration between institutions from different countries. The experience of the United Nations Intergovernmental Panel on Climate Change (IPCC), created in 1988, is an eloquent example of a new modus operandi of the interface of research with public policies. The IPCC has been producing regular reports with analyses, prognoses and recommendations underpinning vital scientific works. It brings together hundreds of researchers and guides government decisions to alert and prevent climate risk and serves as an institutional model for creating similar structures at national scales.

Since it depends on the science timing and a complex web of negotiations to reach consensus among the members of the United Nations, the publication of the IPCC reports every six years – and especially their recommendations to decision-makers – cannot keep up with the frequency to which extreme events occur.

However, one thing is sure: the IPCC reports can point out with very high accuracy that the anthropogenic climate change process has not only accelerated, but it also reached worrying levels in terms of impacts, with significant consequences in the medium and long term(IPCC, 2021). We are talking about fundamental knowledge such as alerts and subsidies to political action of mitigation and adaptation. The latest report, the AR6, warns that the increase in global surface temperatures observed in the last 50 years has been higher than in all other periods for the past 2000 years, with the past 5 being the warmest years since 1850 (IPCC, 2021). Besides, it warns that extreme events' occurrence may increase as never before, even if the global surface temperature increase of 1.5°C is maintained.

Some necessary advances may be creating more knowledge, increasing the speed of data generation, collaboration, overcoming impasses due to denialist conducts and seeking convergences. However, this is not enough if, despite the warnings, business-as-usual attitudes continue irresponsible and evasive. Decision-makers procrastination facing adaptative measures and mitigation investments is due to a short-term vision and belief that disasters are unlikely to occur, especially during their political tenure. Even if some maintain rhetoric in line with climate risk alerts, they continue to act opportunistically by choosing to allocate investments in works with greater immediate visibility or postponing regulatory measures that inhibit emission-intensive or degrading activities of ecosystems and their valuable environmental services. They expose a large population and the economy to risk. The intensity and frequency to which material, environmental, human lives are damaged show it makes no sense to continue betting on luck. Disasters are already part of everyday life and force us to think collectively, looking for convergences, and thinking outside the box (and with no prejudices). It is more explicit, day after day, that the costs of adaptation and mitigation are much lower than the damage caused by climate disasters.

In addition to the many lessons that the Covid-19 pandemic gave, the 2021 climate disasters also need to be a lesson. The reduction of inertia and the easing of the gap between knowing there is imminent risk and acting to prevent environmental and human disasters are urgent. As this year confirmed, this can also happen at home, without distinction between more or less developed countries.

Thus, we are growingly receiving alerts that climate disasters punishing our planet are not just natural phenomena. They can also express nature's reaction to the combination of two types of human conduct: the excess of activities that cause greenhouse gas emissions and the lack of actions for adapting and mitigating the effects of these emissions.

This issue of SeD features ten articles in the *Varia* section.

In the first article, Gonçalves *et al*. analyze the variations in land use and land cover in the Macrometropolis of São Paulo and its implications for water resilience under climate change. The authors identify the most vulnerable municipalities and some possible paths to coordinated local and regional actions. Martin and Martins then present an analysis of the potential of photovoltaic generation and supply in the state of São Paulo and its possible implications regarding the sustainability and independence of a centralized generation. Kilian, Triches and Ruiz focus on sustainability and the water footprint analysis of food available in university restaurants, indicating the need for a review of menus and a better dialogue with consumers on the topic of food and sustainability. Finally, in this block, Carvalho, Iwama and La Rovere present scenarios for oil palm expansion in degraded and deforested areas of the Brazilian Amazon for biodiesel demand. They highlight the need for public policies aimed at the recovery of these areas for palm oil cultivation.

From a historical perspective, Ribeiro and Vieira discuss the trajectory and resilience of an agroextractive settlement project in Pará. They point out that the transition from sugarcane to açaí allowed riparians to experience changes and create conditions to reorganize in settlements. Prioste, Formiga-Johnsson and Ohnuma Júnior present a content analysis around the historical influence of ancient societies' ideas regarding sustainable water management in Rio de Janeiro. They observe that society replicates some models of sustainable management. Bertuluci, Ferreira, and Silva Júnior debate the Anthropocene idea and indicate how the different approaches mobilized by the Anthropocene central issue imply theoretical movements of redefinition of the relations between agency, structure and social change in the historical context of modern industrial societies.

Finally, Ortiz-Paniagua, Valencia and Esparza analyze the University Social Responsibility policy of a Mexican university. They offer a model that helps to identify focus areas and sectors for better performance. Perez-Castillo presents an impact assessment methodology based on benefit indicators for agroecological producer markets also tested in Mexico. And lastly, Matte *et al*. discuss the potential of dialogue networks as tools for rural women recognition and overcoming their traditional marginalization in the field. They present recommendations on the need for actions and policies that provide environments that reframe women role in society and families.

Enjoy your reading!

NOTES

Available in: https://global-flood-database.cloudtostreet.ai. Acessed: 6 Aug 2021.

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Editorial

Enfrentando desastres não-tão naturais

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

doi:10.18472/SustDeb.v12n2.2021.39361

A climatologia é um dos campos científicos que mais avançaram nas últimas décadas, fruto da confluência de fatores ligados à evolução científica e tecnológica. O desenvolvimento das tecnologias satelitais permitiu um incremento notável na disponibilidade e precisão dos dados. Paralelamente, o avanço da ciência da computação tornou possível a evolução de modelos cada vez mais complexos, consistentes e capazes de tratar amplas bases de dados, tanto qualitativa quanto quantitativamente. Os resultados têm sido progressivamente mais confiáveis, o que permite simular cenários e detectar tendências para uma tomada de decisão mais informada. Prova desse avanço é um recente artigo de Tellman et al. (2021), que analisaram dados disponíveis de áreas inundadas entre 2000-2018 (com uma resolução de 250 m), identificando uma área afetada de 2,23 milhões de km2, e um total entre 255 e 290 milhões de pessoas diretamente impactadas por esses eventos no mundo. Isso representa um aumento entre 58 e 86 milhões de pessoas entre 2000 e 2015, um número dez vezes maior que o estimado por outros estudos. A Global Flood Database1, produzida por aqueles pesquisadores, deverá auxiliar na identificação, entre vários impactos, de áreas mais vulneráveis e com maior necessidade de medidas de adaptação, principalmente diante das mudanças climáticas.

No entanto, apesar desses notáveis avanços, cientistas climáticos reconhecidos admitem que não foi possível prever diversos eventos extremos recentes, mesmo nos países que hoje demonstram um compromisso político e científico com a preservação do meio ambiente e com o combate às mudanças climáticas, como a Alemanha. Mesmo com a ciência trazendo vários alertas, ao longo de décadas, de que o rápido aquecimento global traria piores episódios de chuva e ondas de calor mais intensas, as ferramentas de que dispomos ainda não são suficientemente potentes para projetar com precisão o nível de gravidade, o momento exato e a localização da manifestação desses extremos.

Vale ressaltar, no entanto, que modelos que apontem com precisão os desastres não são suficientes para evitá-los. Deve-se focar na implementação de políticas de planejamento, acatar as recomendações e investir na prevenção dos desastres, inclusive com realocação de pessoas e instalações em locais fora das áreas de risco.

Inundações na Europa e na China; incêndios florestais nos Estados Unidos, na Grécia e na Turquia; ondas de calor extremo no Canadá, ou mesmo na Sibéria; déficit hídrico no Brasil, incluindo uma nova crise energética em plena pandemia de Covid-19; e eventos climáticos de grande intensidade na Austrália e na África são exemplos recentes de uma onda de extremos no mundo. Apesar de os impactos das mudanças climáticas serem geralmente maiores nas regiões mais vulneráveis socioeconomicamente, o que aconteceu na Alemanha e no Canadá, por exemplo, demonstra que os desastres climáticos podem ser democráticos e equitativamente letais no mundo inteiro.

A cultura do descompromisso com o investimento em prevenção e a crença de que o desastre não virá resultam em uma contabilização de prejuízos com custo econômico muito maior de remediação do que teria sido o da prevenção. Se fossem ouvidos os atingidos, ficaria patente que desastres em magnitudes menores já haviam ocorrido, e sem a devida atenção das autoridades. A repetição, com aumento de magnitude, é uma expressão da falta de decisão política.

Em face a esses desastres (não tão) naturais, os computadores são fundamentais para a previsão do tempo e das alterações climáticas. A informática sustenta, sem dúvida, o desenvolvimento da ciência do clima. Mesmo que muito elevados, os custos de melhores e maiores computadores, e do apoio à pesquisa, são insignificantes em comparação com as perdas materiais, econômicas e humanas associadas aos eventos extremos para os quais a sociedade não está preparada.

As pesquisas ainda precisam evoluir no sentido de conseguir prever os locais, os momentos, a intensidade e a recorrência cíclica com que os países irão enfrentar extremos como ondas de calor ou enxurradas, ou seja, os dados e os modelos ainda podem e devem ser mais refinados.

Mas a solução não passa unicamente por comprar novos computadores e investir em pesquisas que preencham as lacunas de informação. Falta ação, e não somente política! Falta inteligência coletiva e criativa, orientada à geração de soluções em tempo real. Redes de pesquisadores inter e transdisciplinares (com um pé na academia e outro no âmbito social, privado ou governamental) devem continuar gerando conhecimentos que inspirem ações e transformações, por meio de colaboração entre instituições de diferentes países. A experiência do Painel Intergovernamental sobre Mudanças Climáticas (IPCC), das Nações Unidas, criado em 1988, é um exemplo eloquente de um novo modus operandi da interface da pesquisa com as políticas públicas. Reunindo centenas de pesquisadores, o IPCC vem produzindo relatórios sistemáticos com análises, prognósticos e recomendações, que fundamentam importantes trabalhos científicos, orientam decisões governamentais de alerta e prevenção do risco climático e servem de modelo institucional para a criação de estruturas semelhantes em escala nacional.

Em função dos tempos da ciência e também da complexa teia de negociações para se obter consensos no âmbito dos países-membros das Nações Unidas, a publicação, a cada seis anos, dos relatórios do IPCC e, em particular, suas recomendações aos tomadores de decisão não conseguem acompanhar a frequência com que os eventos extremos estão ocorrendo.

Mas uma coisa é certa: os relatórios do IPCC têm condições de apontar com altíssima confiabilidade que o processo de mudanças climáticas de natureza antropogênica não apenas se acelerou, mas também vem atingindo níveis preocupantes em termos de impactos, cujas consequências são graves no médio e longo prazo (IPCC, 2021). São conhecimentos fundamentais, como alertas e subsídios à ação política de mitigação e adaptação. O mais recente relatório, o AR6, alerta que o aumento da temperatura da superfície global observado nos últimos 50 anos foi maior do que todos os outros períodos nos últimos 2000 anos, com os últimos cinco anos sendo os mais quentes desde 1850 (IPCC, 2021). Ademais, há previsão de aumento nos eventos extremos como nunca antes observado, mesmo que se consiga manter o aumento de temperatura da superfície global no nível de 1,5^{o}C.

Gerar mais conhecimento, incrementar a velocidade da geração de dados, aumentar a colaboração, superar impasses gerados por condutas negacionistas e procurar convergências são avanços necessários. No entanto, isso não é suficiente se, a despeito dos alertas, ainda persistem condutas do tipo business as usual, irresponsáveis e evasivas. Tomadores de decisão que procrastinam medidas de adaptação e investimentos em mitigação são movidos pela visão de curto prazo e confiam que os desastres são pouco prováveis de ocorrer, principalmente durante seus mandatos políticos. Mesmo que alguns mantenham uma retórica em sintonia com os alertas sobre riscos climáticos, agem de modo oportunista, ao optarem por alocar investimentos em obras com maior visibilidade imediata, ou ao postergarem medidas regulatórias que coíbam atividades intensivas em emissões ou degradantes aos ecossistemas e seus preciosos serviços ambientais. Expõem, assim, grandes contingentes de população e a economia ao risco. A intensidade e a frequência dos danos ambientais, materiais e humanos estão mostrando que não faz sentido seguir apostando na sorte: os desastres já são parte da vida quotidiana e nos obrigam a pensar de maneira coletiva, procurando convergências e pensando fora da caixa (e dos preconceitos). Está cada vez mais claro que os custos da adaptação e da mitigação são muito menores do que os prejuízos causados pelos desastres climáticos.

Para além das muitas lições que a pandemia da Covid-19 vem deixando, os desastres climáticos de 2021 também precisam servir como lição. É imperativo que se reduzam a inércia e o fosso entre saber que há risco iminente e, efetivamente, agir para evitar catástrofes ambientais e humanas, que, como este ano confirmou, também podem acontecer em casa, sem distinção entre países mais ou menos desenvolvidos.

Em suma, estamos cada vez mais diante de evidências de que os desastres climáticos que castigam o nosso planeta não são apenas fenômenos naturais. São, também, a expressão da reação da natureza à combinação de dois tipos de conduta dos humanos: por um lado, um excesso de atividades que provoca emissões de gases de efeito estufa; por outro, uma falta de ações voltadas à adaptação e à mitigação dos efeitos dessas emissões.

A presente edição da SeD apresenta dez artigos na seção *Varia*.

No primeiro artigo, Gonçalves *et al*. analisam as variações no uso e na cobertura da terra na Macrometrópole Paulista e as suas implicações para a resiliência hídrica diante das mudanças climáticas, identificando municípios mais vulneráveis e alguns possíveis caminhos para ações coordenadas locais e regionais. Em seguida, Martin e Martins apresentam uma análise do potencial de geração e suprimento fotovoltaicos no estado de São Paulo, e as possíveis implicações no tocante à sustentabilidade e à independência da geração centralizada. Já Kilian, Triches e Ruiz se debruçam sob a análise da sustentabilidade e da pegada hídrica da alimentação disponibilizada em restaurantes universitários, indicando a necessidade de revisão de cardápios e maior diálogo com os consumidores sobre o tópico alimentação e sustentabilidade. Por último, nesse bloco, destacamos o trabalho de Carvalho, Iwama e La Rovere sobre cenários para a expansão da palma de óleo em áreas degradadas e desflorestadas na Amazônia brasileira para a demanda de biodiesel, indicando a necessidade de políticas públicas voltadas à recuperação dessas áreas para o cultivo de dendê.

Já com uma perspectiva histórica, Ribeiro e Vieira discutem a trajetória e a resiliência de um projeto de assentamento agroextrativista no Pará, apontando que a transição do cultivo de cana-de-açúcar para o de açaí permitiu que ribeirinhos experimentassem mudanças e criassem condições para se reorganizarem em assentamentos. Já Prioste, Formiga-Johnsson e Ohnuma Júnior realizam uma análise de conteúdo da influência histórica dos pensamentos das sociedades antigas em relação à gestão sustentável das águas das chuvas no Rio de Janeiro, apontando que alguns modelos de gestão sustentável são replicados pelas sociedades. Bertuluci, Ferreira e Silva Júnior debatem a ideia do Antropoceno e indicam como as diferentes abordagens mobilizadas pela ideia-força de Antropoceno implicam movimentos teóricos de redefinição das relações entre agência, estrutura e mudança social no contexto histórico das sociedades industriais modernas.

Por fim, Ortiz-Paniagua, Valencia e Esparza analisam a política de Responsabilidade Social Universitária de uma universidade mexicana, por meio da proposição de um modelo que auxilia na identificação de áreas e setores a serem mais bem trabalhados para um melhor desempenho. Já Perez-Castillo apresenta uma metodologia de avaliação de impacto baseada em indicadores de benefícios para mercados de produtores agroecológicos, testada também no México. E, por último, Matte *et al*. discutem o potencial das redes de diálogo como ferramentas de valorização das mulheres rurais e de superação da sua tradicional marginalização no campo, com recomendações sobre a necessidade de ações e políticas que propiciem ambientes que ressignifiquem o papel das mulheres na sociedade e no núcleo familiar.

Boa leitura!

NOTAS

Disponível em: https://global-flood-database.cloudtostreet.ai. Acesso em: 6 ago. 2021.

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Land use and land cover changes in São Paulo Macro Metropolis and implications for water resilience under climate change

Variações no uso e na cobertura da terra na Macrometrópole Paulista e implicações para a resiliência hídrica sob mudanças climáticas

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doi:10.18472/SustDeb.v12n2.2021.32146

Received: 19/06/2020
Accepted: 28/06/2021

ARTICLE – VARIA

ABSTRACT

The São Paulo Macro Metropolis (MMP) is a geographical arrangement that brings together the most significant Brazilian socioeconomic figures and faces numerous challenges, such as heavy pressure on natural resources. Through compilation, spatialization and cross-referencing of data, this work

assessed time series of land use and land cover of the last decades, the water supply status in an urban environment and climate data projection for MMP. Municipalities with different profiles were identified: those with positive final balances and those with negative final balances about the maintenance of their natural areas. Furthermore, more than half of the municipalities of the MMP have low water supply assurance, which can be aggravated due to climate change, as predicted in several climate models. The characterization of municipalities based on this information allowed identifying which of them are the most vulnerable, and these results indicate paths for coordinated actions at local and regional levels to increase water resilience in the macro-region.

Keywords: *São Paulo Macro Metropolis. Land use and land cover changes. Ecosystem services. Water supply.*

RESUMO

A Macrometrópole Paulista (MMP) é um arranjo geográfico que reúne os mais significativos números socioeconômicos brasileiros e enfrenta inúmeros desafios, como a grande pressão sobre os recursos naturais. Por meio da compilação, espacialização e do cruzamento de dados, este trabalho avaliou séries temporais de uso e ocupação da terra das últimas décadas, a situação do abastecimento de água no meio urbano e dados de projeção climática para a MMP. Foram identificados municípios com perfis distintos: os que apresentam saldos finais positivos e os que apresentam saldos finais negativos com relação à manutenção de suas áreas naturais. Além disso, mais da metade dos municípios da MMP possui baixa garantia hídrica, o que pode ser agravado devido às mudanças climáticas, como previsto em diversos modelos climáticos. A caracterização dos municípios a partir dessas informações permitiu identificar quais deles são os mais vulneráveis, e esses resultados indicam caminhos para ações coordenadas nos níveis locais e regionais para fins de ampliação da resiliência hídrica na macrorregião.

Palavras-chave: Macrometrópole Paulista. Mudanças de uso e ocupação da terra. Serviços ecossistêmicos. Abastecimento urbano.

1 INTRODUCTION

In 1950, there were only two "megacities" – urban agglomerations with 10 million inhabitants or more – on the planet: New York and Tokyo (UN, 2015). In 2014, 18 countries already had 28 megacities, with Rio de Janeiro and São Paulo as the two Brazilian megacities (UN, 2015). The discussion on megacities draws attention in the so-called "emerging" countries, such as China, India and Brazil (UN, 2015), because the populations concentrated in urban centres increasingly represent impacts on these centres and their surroundings.

While in megacities there is a growth guided by industries, commerce, ports and airports, knowledge centres and highly complex technological initiatives, there is, in addition, the growth of problems common to metropolises, such as poverty, violence, corruption, inequality, deterioration in buildings, insalubrity, water supply, pollution and traffic congestion (THE STATES OF THE WORLD'S CITIES, 2004, 2005). Furthermore, as already detected by Di Giulio *et al*. (2017) and Urbinatti and Ferreira (2019), there is great pressure on natural resources and major environmental challenges represented by the loss of ecosystem services, changes in the urban microclimate, inadequacies in the characteristics of land use, which are enhanced when megacities are conurbated with other large metropolises. To deal with these problems, as Graafland (2006) points out, it is necessary to understand cities beyond their political limits, with approaches that represent their spatial, social, environmental and economic realities.

In the Brazilian context, the São Paulo Macro metropolis (MMP) is considered one of these urban conurbations (Figure 1), in which are included, in addition to the megacity of São Paulo, composed of the municipalities of its Metropolitan Region, five other Metropolitan Regions, two Urban Agglomerations and a Regional Unit in the state of São Paulo, representing 21.5% of the state and 20% of the protected natural heritage of the state (EMPLASA, 2019).

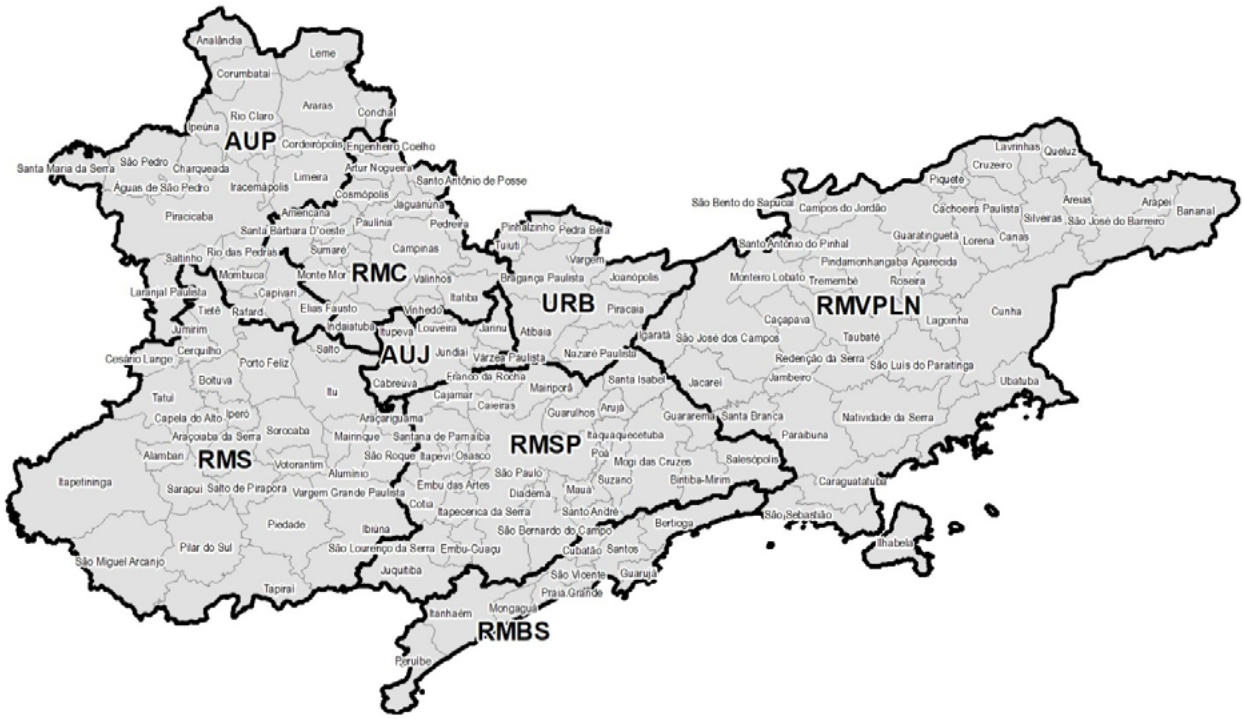

Figure 1 | Municipalities of the São Paulo Macrometropolis grouped into their Metropolitan Regions, Urban Agglomerations and Regional Unit – Urban Agglomeration of Jundiaí (AUJ), Urban Agglomeration of Piracicaba (AUP), Metropolitan Region of Baixada Santista (RMBS), Metropolitan Region of Campinas (RMC), Metropolitan Region of Sorocaba (RMS), Metropolitan Region of São Paulo (RMSP), Metropolitan Region of Paraíba Valley and North Coast (RMVPLN) and Regional Unit of Bragantina (URB).

Source: Own elaboration.

The dynamics and characteristics of growth/development/degrowth of the MMP may determine greater or lesser propensity for the commitment, and even exhaustion, of important ecosystem services. These defined, according to the Millennium Ecosystem Assessment (MEA, 2003), as the benefits obtained from ecosystems, on which human beings are fundamentally dependent and which are categorized into provisioning services such as water, food and fuel; regulating services, such as climate regulation and water purification; cultural, such as recreational, aesthetic and educational benefits; and supporting services, such as nutrient cycling and soil formation.

There is a lack of studies on scenarios and projections of this natural capital that can technically and scientifically support the formulation of public policies for future years. In this sense, this work aims to assess time-series of land use and land cover data, seeking to identify, group and order the municipalities of the MMP in evolution profiles of areas of provision of ecosystem services, especially water production, relating them with the water supply situation for the urban environment and annual projections for climatic variables. For this reason, it pursuits to visualize the regions and municipalities of the MMP as a whole, pointing out those in a more critical situation concerning ecosystem services, using as a basis for analyzing the natural coverage of their territory.

1.1 LITERATURE REVIEW

The area of cities, compared to the limits of their municipalities, is generally small, but urbanization is still a human activity with the potential to provoke intense changes in land use, with strong impacts and consequences (ROCKWELL, 2009). Urbanization is one of the most impactful processes on the environment (CARVALHO; BRAGA, 2001), and the lifestyle practised in the major cities of the world generates high demand for energy, pollution, degradation of natural resources and greenhouse gases emission (FARIA, 2009; HOGAN *et al*., 2001).

When associated with the impacts of climate change, urban problems intensify rising temperature, rising sea levels in coastal cities, heat islands, floods, water and food shortages, ocean acidification and impacts of extreme events (PBMC, 2016). These problems have created new challenges, such as water shortages caused by prolonged droughts, the proliferation of disease vectors such as dengue, zika, chikungunya and leptospirosis, and the increase in respiratory diseases related to climate and/or pollution.

The effects of urbanization have motivated studies currently called "water-food-energy nexus", which analyze the interdependence between these sectors, necessary to ensure human well-being, poverty reduction and sustainability (FAO, 2014). Changes in one of these sectors may have impacts on the other two, considering the high demand for its products and the managerial challenge of properly balancing the use of water for human supply, irrigation, electricity production, among others (AHMADI *et al*., 2020; FAO, 2014; SOUSA JÚNIOR, 2018). In the demographic transition and the transition of urban water consumption in Brazil, Carmo *et al*. (2014) point out the importance of the relationship between demographic dynamics and its consequences for water demand and use.

Water scarcity triggers conflict situations around complex water supply systems. Contrary to common sense, the metropolitan region of São Paulo is part of an area of insufficient availability of clean water, in a region of hydrological complexity (JACOBI; TORRES; GRESSE, 2019). This situation poses the challenge of improving equity in the distribution of water in the metropolis, strengthening access to the public water supply system, in addition to guaranteeing supply over time.

The year 2014 was the driest in the history of the State of São Paulo since data began to be recorded in the 1930s. Between 2013 and 2015, the water levels of the main reservoirs in the Metropolitan Region of São Paulo (RMSP) decreased drastically due to an extreme drought phenomenon, which affected more than 20 million people. The low levels of precipitation recorded in the summer of 2020, in front of reservoirs with very low volumes, foreshadow a new water crisis, which is already revealed in the restrictions of hydroelectric generation (JACOBI; TORRES; GRESSE, 2019).

Drought events have increased in frequency and their consequences for the supply of water and energy are reflections of climate change that require investment in adaptation policies for the RMSP, as pointed out by Sousa Júnior *et al*. (2016).

The basins of the Billings and Guarapiranga dams, in São Paulo, are important regions that provide ecosystem services, in particular, the production of water for public supply. Although protected by land use planning since the 1970s (watershed protection and recovery laws), these basins are strongly pressured by the use of the land around the dams, not directed to preservation (PMMA SÃO PAULO, 2017).

According to Kowarick (2002), the characteristics of land use and land cover are forcing factors that determine not only the growth and development of cities but also the consequences and impacts of the latter. As an example, the author points to housing issues as contributors to determine the urban

lifestyle. In the case of the city of São Paulo, as pointed out by Leonel *et al*. (2019) and Sampaio and Pereira (2003), a significant part of the population of São Paulo is still homeless or lives in precarious conditions, due to a lack of infrastructure services (sanitation, urban waste collection, among others) or because it is located in areas at risk of landslides, flooding and fire, due to poor electrical connections.

Sampaio and Pereira (2003) already identified elements in the National Policy on Protection and Civil Defense (PNPDEC) and in the Strategic Master Plan (PDE) of São Paulo to prevent new occupations in risk areas. These plans also provided for the urbanization of needy areas and actions for "Social and Territorial Equity and Inclusion" as a way to reduce the contrast between accumulation and poverty.

On the other hand, Amato-Lourenço *et al*. (2016) point out that the creation of green areas can minimize the effects of urban expansion, such as the suppression of vegetation cover, in addition to contributing to the improvement of the population's quality of life. In São Paulo, projects such as the creation of 100 urban parks (SECRETARIA MUNICIPAL DO VERDE E MEIO AMBIENTE, 2012) and the São Paulo City Green Belt Biosphere Reserve (RBCV) seek to alleviate the pressure generated by urbanization on water springs and water sources, as noted by Rodrigues *et al*. (2006).

Environmental heritage, ecosystem services, protection of water resources through Payments for Environmental Services (PES) (PAVANI *et al*., 2020), reforestation and erosion scenarios, pasture and forest areas estimates and changes between these categories, all these aspects are interconnected in the analysis of the MMP. The analysis of the land use and land cover dynamics is, therefore, fundamental for assessing uses, dependence and impacts on the provision of ecosystem services. Its use is ideal for the macro-regional context of insertion of the MMP. According to Verburg *et al*. (2009), the quantification of specific features and their relationship with ecosystem functions provide an important information base for policy development and territorial planning.

Adaptive governance focused on experimentation and learning, which brings together actors to collaborate in collective actions for conflict resolution (FOLKE *et al*., 2005), has been suggested to face contexts such as the 2013-2015 water crisis. According to Torres and Jacobi (2020), such issues need to be dealt with at a macro-regional scale in the context of participatory management. However, there is a mismatch in the negotiation between civil society and government, as detected by Marques *et al*. (2020), who, on the other hand, identify opportunities for engagement between civil society and academia for water governance.

2 METHOD

The study area of this paper, the São Paulo Macro Metropolis (MMP), covers 53.4 thousand km^2, with 174 municipalities (50% of the urbanized area of the state of São Paulo), which represented 74.7% of the state population, in 2018, and 81.9% of the state GDP in 2016 (EMPLASA, 2019). Of this population, according to the 2010 Census (IBGE, 2010), 2.68 million people lived in subnormal agglomerates (EMPLASA, 2019). The MMP covers the following metropolitan regions: Urban Agglomeration of Jundiaí (AUJ), Piracicaba Urban Agglomeration (AUP), Metropolitan Region of Baixada Santista (RMBS), Campinas Metropolitan Region (RMC), Metropolitan Region of Sorocaba (RMS), Region Metropolitan Region of São Paulo (RMSP), Metropolitan Region of Paraíba Valley and North Coast of São Paulo (RMVPLN) and Regional Unit of Bragantina (URB).

To support the analysis, 3 data sets were used, which were processed and assigned in the mesh of municipalities of the MMP's cutout and arranged by period, as shown in Figure 2.

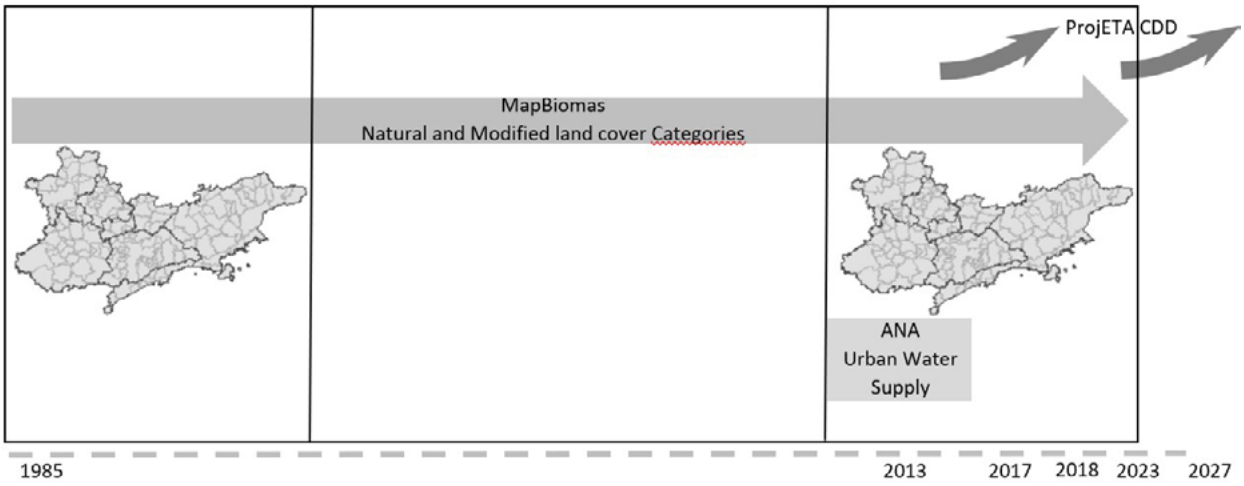

Figure 2 | Diagram with data considered as a support for work analysis: MapBiomas Transitions 1985-2018; Atlas ANA 2013 of Urban Water Supply; Projection of the Projeta's CDD variable in the periods from 2013 to 2017 and 2023 to 2027.

Source: Own elaboration.

Data related to land use and land cover are made available by MapBiomas; by CPTEC/Inpe, the data related to the projections of climate variables; and by the National Water Agency (ANA), data related to Urban Water Supply.

MapBiomas (MAPBIOMAS PROJECT, 2019) is a multi-institutional initiative that systematically produces and disseminates land use and land cover data for the entire Brazilian territory, detailing the transitions that have taken place annually in 27 categories since 1985. Coverage and transitions data are available in *raster* format, suitable for the production of maps and geoprocessing operations, and in electronic spreadsheet format, with the quantitative areas, grouped by biomes, states and municipalities.

For this work, the land cover *raster* data categories were grouped as shown in Table 1, showing the mapping with only two groups of categories: Natural and Modified. The Natural group includes the preserved natural environment categories, and the Modified group includes the categories in which there have been anthropogenic land cover changes. This grouping seeks to distinguish the categories with the greatest potential for providing ecosystem services from those with the lowest potential for conventional economic activities and other occupations. It is important to emphasize that the transitions between categories occurred from the Natural group to the Modified and vice versa, and, therefore, the increase of areas in the Natural group may refer not exactly to natural areas, but also to regions that, at some point, were intended for recovery and regeneration.

Table 1 | Grouping of land use and land cover categories in MapBiomas.

Natural	*Modified*
Rocky Outcrop	Agriculture
Salt Flat	Forest Plantation
Natural Forest	Urban Infrastructure
Grassland	Mining
Other Non-Forest Natural Formation	Mosaic of Agriculture and Pasture
Beach and Dune	Non Observed
River, Lake and Ocean	Other Non-Vegetated Area
	Pasture

Source: Own elaboration

Two groups were made considering absolute values regarding area and percentage of transitions so that it was possible to identify the municipalities with the greatest loss and those with the greatest gain of areas in the Natural group in the period analyzed. Thus, the municipalities with the highest transition rate and the current *status* of coverage are identified with the categories with the highest potential for offering ecosystem services.

Regarding climate data, CPTEC-Inpe used the ETA regional model and performed the downscaling of the global models BESM, HadGEM2-ES, MIROC5 and CanESM2, and obtained the climate variables projections with annual, monthly, daily and 3-hour frequency for South America for the period 2006 to 2099 in the RCPs (*Representative Concentration Pathway*) 4.5 and 8.5 scenarios (CHOU *et al*., 2014a; CHOU *et al*., 2014b; and LYRA *et al*., 2018).

For this study, it was used the variable Annual Mean of Maximum Number of Consecutive Dry Days (CDD) of the annual climate projections of the ETA HadGEM RCP 4.5 model, which is available with a spatial resolution of 5 kilometres for the states of the southeastern region of Brazil on the Projeta platform (CPTEC/Inpe, 2020). This index was selected for being able to indicate periods of low rainfall and conditions that favour drought. These data are temporally divided from 1961 to 2005, the period in which they represent the results of the model using observed data, and from 2006 to 2099, the projection period for climate scenarios.

Data on the water supply to the population are found in the Atlas Brazil – Urban Water Supply by the National Water Agency (ANA, 2020) and are also part of this work. In it, each Brazilian municipality is classified as follows: “satisfactory supply”, in which the municipality does not present criticality in terms of water source or water supply infrastructure; “expansion of the production system”, in which the municipality does not present water supply problems, but there is a need to expand the units of the production system; “low water assurance”, in which the water supply system of the municipality needs a new water body or is in a condition of rationing, collapse or alert (in 2013); and “no information”.

3 RESULT

3.1 LAND USE AND LAND COVER CHANGES

Considering the use and coverage transitions identified in the MapBiomas data for the MMP cutout, there was a reduction of 0.26% in the Natural group categories in the MMP throughout the period from 1985 to 2018. Although the percentage is practically nil, this does not mean the absence of transitions in the period, because the transitions of the categories occurred in both directions: from the Natural group to the Modified group and vice versa, oscillating over the years.

Land use and land cover transitions history culminates in the most recent data from 2018, which show the current panorama of the landscape, and, through them, it is possible to identify regions with different characteristics regarding the maintenance of areas in the Natural category, as seen in Figure 3, with the representation of the percentage of area in the Natural category of each municipality.

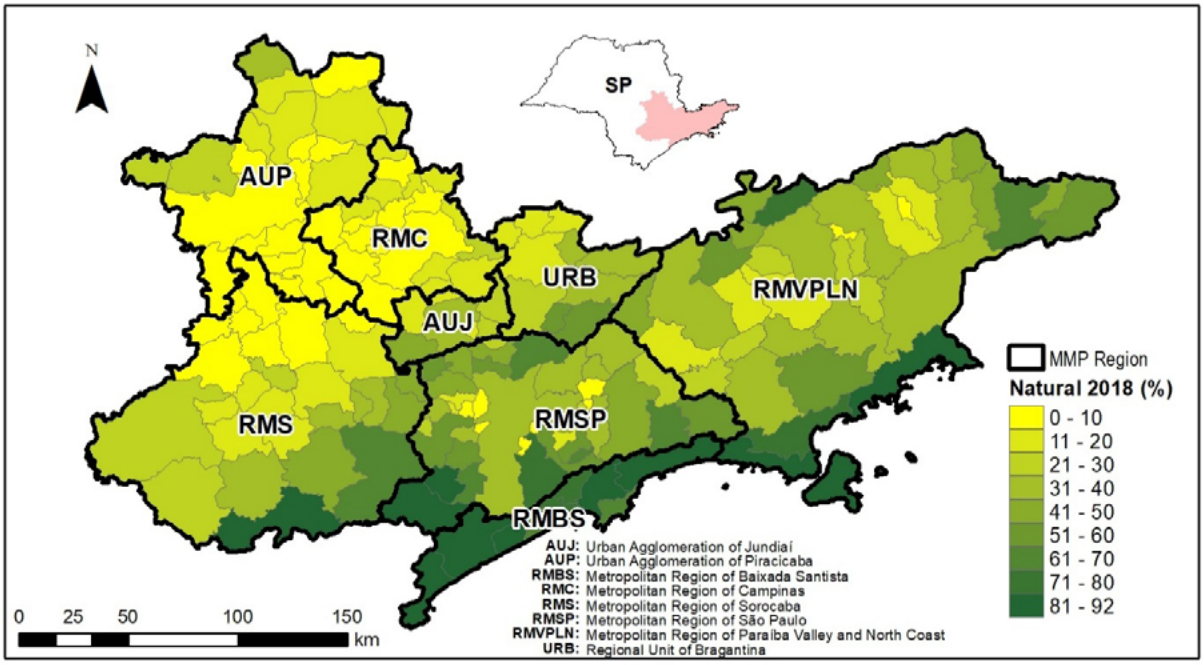

Figure 3 | Municipalities of the MMP and respective percentages of Natural coverage in 2018.

Source: Elaborated by the authors from MapBiomas data (MAPBIOMAS PROJECT, 2019).

Most municipalities in the Metropolitan Regions of Campinas and Sorocaba and the Urban Agglomeration of Piracicaba have less than 20% of their coverage among those categorized as Natural. These municipalities form a continuous block that expands to the Urban Agglomeration of Jundiaí and the Regional Unit of Bragantina. On the other hand, there are municipalities with more than 80% of coverage categorized as Natural, which are concentrated in the coastal strip of the state, with emphasis on the Metropolitan Region of Baixada Santista, with most of its municipalities with this characteristic.

When analyzing other municipalities, it is possible to observe that the percentage of the Natural group of São Caetano do Sul is 0.1%, and, on the other hand, 92% of the territory of Ubatuba belongs to the Natural group, and even so, there was a transition of 0.8% from the Modified group to the Natural group. This fact partially reflects the results found by Farinaci (2012) in research about the intention of rural producers to expand forest areas on their properties. According to the author, in municipalities such as Ubatuba, Monteiro Lobato and São Luiz do Paraitinga, the answer was affirmative, while in municipalities such as Campinas, Jundiaí and São José dos Campos, most producers do not intend to increase forests.

Figure 4 shows the history of the municipalities of the MMP regions according to the percentage of the accumulated final balance of the transition period from the Natural group to the Modified group. That is, in 33 years, the final balance indicates that there were municipalities that eliminated up to 18.5% of their area with transitions from the Natural to the Modified group and municipalities that increased by up to 9.6% of their area with transitions from the Modified to the Natural group. In terms of absolute values, some municipalities suppressed up to 55 km² of the categories of the Natural group and, as well, municipalities that increased up to 41 km² of these categories.

The numbers of transitions in the municipalities were grouped considering the final balance of the Natural group with the absolute values of the area and, also, the final balance of the Natural group as a percentage of the municipality's area. For both area and percentage, the 5 municipalities in the MMP with the highest and lowest balance at the end of the period were identified.

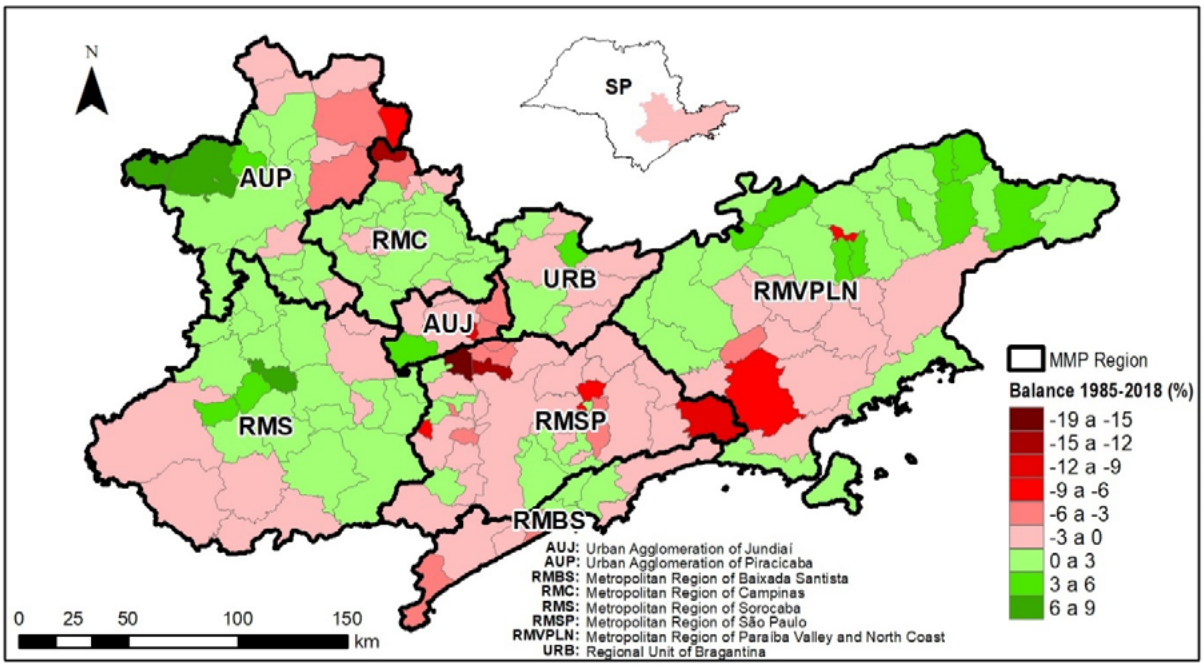

Figure 4 | Map with the percentage of land cover transitions between 1985 and 2018 in the MMP. Shades of red indicate loss of natural areas, and shades of green indicate gain.

Source: Elaborated by the authors from MapBiomas data (MAPBIOMAS PROJECT, 2019).

According to the final balance, as shown in Table 2, the AUP, RMC and RMS regions, located in the western MMP, presented a positive percentage concerning the Natural vegetation classes. In the other regions, the percentage was negative, including in the RMVPLN, where the predominance of municipalities with a positive balance in Serra da Mantiqueira and the North Coast was not enough to compensate for the decrease in the other municipalities.

Table 2 | Classification of regions according to the balance of area of the Natural vegetation class from the transitions of categories in the period from 1985 to 2018.

Region	*Population (2019)*	*Area (km²)*	*Natural Balance (km²)*	*Natural Balance (%)*
Metropolitan region of Sao Paulo (RMSP)	21.734.682	7.947	-146	-1,84
Metropolitan region of Baixada Santista (RMBS)	1.865.397	2.429	-49	-2,04
Urban Agglomeration of Jundiaí (AUJ)	815.338	1.269	-10	-0,80
Regional Unit of Bragantina (URB)	434.655	2.768	-8	-0,29
Metropolitan Region of Paraíba Valley and North Coast (RMVPLN)	2.552.610	16.178	-6	-0,04
Metropolitan region of Campinas (RMC)	3.264.915	3.792	17	0,45
Urban Agglomeration of Piracicaba (AUP)	1.495.220	7.368	23	0,32
Metropolitan region of Sorocaba (RMS)	2.143.786	11.611	43	0,37
São Paulo Macro Metropolis (total)	34.306.603	53.362	-137	-0,26

Source: Own elaboration

Regarding the percentage of areas that underwent a transition from Natural to Modified, the municipalities of Cajamar, Caieiras, Engenheiro Coelho, Várzea Paulista and Salesópolis have the highest values (18.5%, 12.6%, 12.2%, 11.4% and 9.6%, respectively). On the other hand, the highest final balances in the percentage of transition from Modified to Natural were in the municipalities of Iperó, Santa Maria da Serra, São Pedro, Águas de São Pedro and Cabreúva (8.5%, 7.9%, 6.8%, 5.2% and 4.8%, respectively).

As for the final balance, in absolute values of areas that underwent a transition from Natural to Modified throughout the period, the municipalities of Paraibuna, Salesópolis, Cunha, Cajamar and Limeira had the highest values (55 km², 41 km², 25 km², 24 km² and 23 km², respectively).

The municipalities of São Pedro, Piracicaba, Santa Maria da Serra, São José do Barreiro and Iperó, on the other hand, had the highest balances in absolute values of transitions from the Modified to Natural categories (41 km², 21 km², 20 km², 17 km² and 14 km², respectively). Thus, the municipalities of Cajamar and Salesópolis stand out with the highest percentages and absolute values of areas transitioning from Natural to Modified categories, and the municipalities Iperó, Santa Maria da Serra and São Pedro stand out with the highest percentages and absolute values of areas in transitions from Modified to Natural categories.

There is, furthermore, a group of municipalities with the lowest percentages of their areas in the Natural categories in 2018. They are the municipalities of São Caetano do Sul, Hortolândia, Sumaré, Cerquilho and Santa Bárbara d'Oeste, with a maximum of 3% of their territory in the Natural categories. On the other hand, the municipalities of Ubatuba, Ilhabela, Tapiraí, Juquitiba and Bertioga present, in 2018, percentages of the area in the Natural categories in approximately 90% of their territory.

The municipality of Cajamar, due to its proximity to the metropolitan region of São Paulo, has several logistic and distribution centres and concentrates its economic activities on the extraction of wood and stone; food, cosmetics, metallurgy and chemical industry; limestone mining, in addition to general product logistics (MDIC, 2018). The economic activities and geographic location of the municipality of Cajamar help to explain the decrease in natural areas verified in the data.

Iperó, representing the opposite, is the municipality with the greatest increase in natural areas and is located in the metropolitan region of Sorocaba. In this municipality, it is inserted part of the Flona de Ipanema, where environmental education activities and awareness of the population have been implemented in the surroundings over time.

At the municipal level, there are still problems in maintaining vegetation areas when new master plans and zoning laws are discussed, especially in areas of environmental protection in the Cerrado. In São José dos Campos, the Cerrado, which covered 30% of the municipal territory, currently represents only 1% of this native coverage (CODAZZI, 2019).

3.2 CLIMATE PROJECTIONS

The annual data of the CDD variable of the climate projection generated by CPTEC/Inpe and made available in the Project Platform were processed for the cut-off of the MMP considering the regional model ETA-HadGEM-ES. These data comprise the historical period from 1961 to 2005, constituted from observed data, and those that comprise the projection period under the RCP 4.5 scenario, from 2006 to 2099.

The CDD climate index is obtained from the Precipitation variable (PREC) data and indicates the number of consecutive days with precipitation less than 1 millimetre in the period in which the highest values may characterize conditions favourable to drought. The historical annual average of the CDD in the MMP was 20.6 (1961 to 2005), the average for the period 2038 to 2042 was 22.7, and the average for the last five years of the projection was 28.1 (end of the 21st century). It can be noted that this is a growing index according to the observation of these 3 averages and is an important reference in urban supply issues, among others.

A great amplitude was observed in this index in the periods from 2013 to 2017 and 2023 to 2027, and the difference in the average for each period is shown in Figure 5. According to the projection, except for some points in the North Coast of São Paulo, the entire MMP will have a longer sequence of dry days in the period from 2023 to 2027 (around 2025), considering the period from 2013 to 2017 (around

2015) as a reference due to the water crisis. In addition to the index not being favourable for the entire MMP in the 10-year projection, there is a range that includes the URB, AUJ, RMC and AUP, in which there is an even greater criticality, with an extension of dry days by approximately another month.

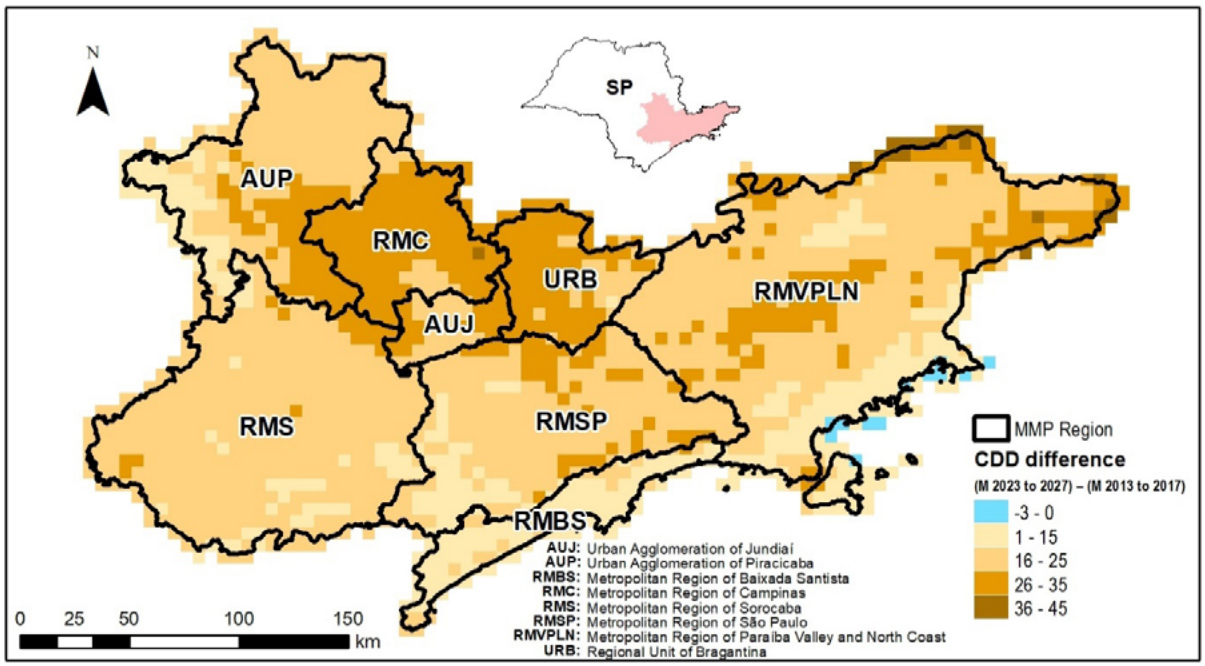

Figure 5 | Map of the MMP representing the difference of the CDD index averages from 2023 to 2027 and 2013 to 2017. The positive values, which occupy almost fully the map, indicate that there was an increase in the index during the two periods.

Source: Elaborated by the authors from Projeta data (CPTEC/Inpe, 2020).

3.3 URBAN SUPPLY

Seeking alternatives to ensure water security is a management challenge, especially when considering the direct effects of climate change on the volume of precipitation, the increasing demand for water supply, industrial use and irrigation in the MMP. It is worth mentioning that some municipalities, such as São Paulo, depend on springs that are beyond their territory.

According to the Master Plan for Utilization of Water Resources to Macrometropolis Paulista, eight Water Resources Management Units are comprised by the MMP: Paraíba do Sul, North Coast, Piracicaba/Capivari/Jundiaí, Alto Tietê, Baixada Santista, Mogi Guaçu, Tietê/Sorocaba and Ribeira de Iguape and South Coast.

The data on the water supply situation of the municipalities of the Urban Water Supply Atlas for the territorial cutout of the MMP are shown in Figure 6, which shows that 58% of the municipalities in the MMP need investment in this area and are in a situation of low water assurance or require expansion of the production system.

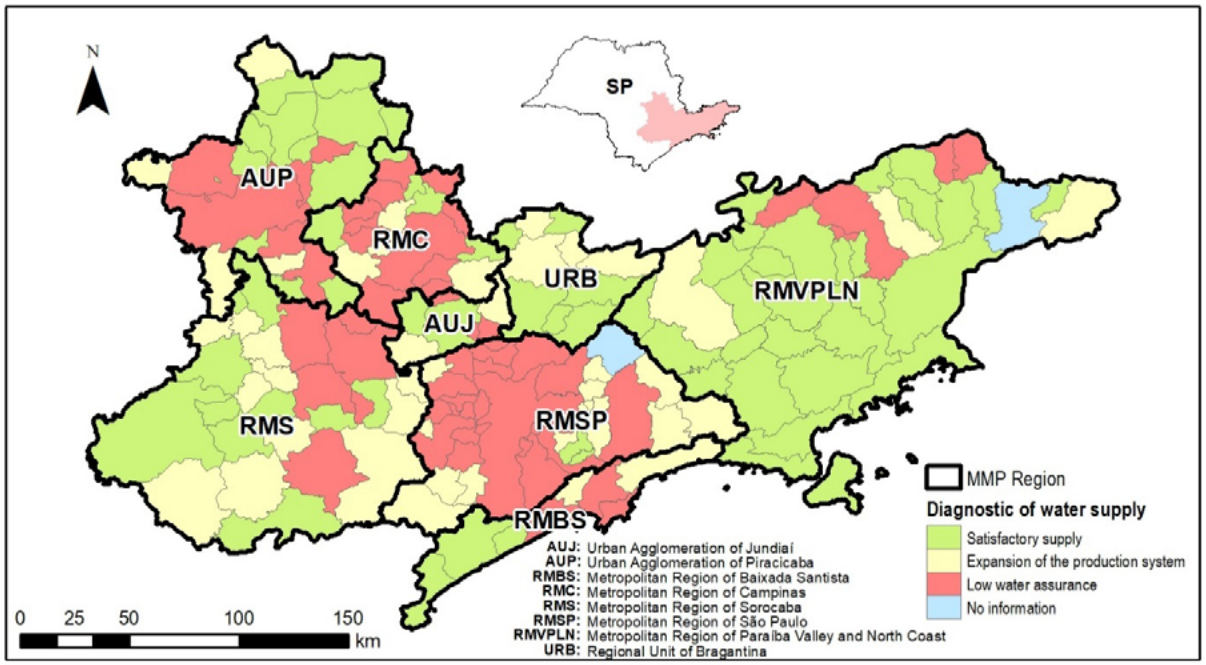

Figure 6 | Map with the qualification of water supply in the MMP, according to the Urban Supply Atlas.

Source: Elaborated by the authors based on data from the Urban Supply Atlas (ANA, 2020).

The map indicates that in all regions of the MMP there are municipalities with low water assurance, except the Bragantina Regional Unit, and that in the two most populous regions, the Metropolitan Regions of São Paulo and Campinas, most of their municipalities are in this situation. It is important to point out that the areas of contribution of water supply systems are beyond the municipal limits, the metropolitan regions and even the MMP, as is the case of the Cantareira Water Supply System, with upstream areas in the state of Minas Gerais. Thus, the supply of water to the population, coming from ecosystem services, originates in other adjacent municipalities.

3.4 CRITICAL MUNICIPALITIES

From the combination of the 3 information compiled and processed, considering the different profiles of the municipalities in the MMP concerning the history of land use and land cover changes, their current natural areas with potential for the production of ecosystem services and the urban supply situation, 20 municipalities whose contexts are more unfavourable were identified (Table 3).

These are municipalities that have less than 20% of their territory with natural coverage, have a negative balance of the maintenance of natural areas and have a diagnosis that indicates a low water assurance or need to expand the water production system.

Table 3 | MMP municipalities with unfavourable characteristics regarding the provisioning of ecosystem services for water production and the need for investment in supply systems (in descending order by the Non-natural Area percentage in 2018).

Region	*Municipality*	*Converted Natural Area (%)*	*Non-natural Area in 2018 (%)*	*Diagnostic of Water Supply*
RMSP	São Caetano do Sul	-0.3	99.9	Low water assurance
RMC	Hortolândia	-0.7	98.6	Expansion of the production system
RMC	Sumaré	-0.2	97.3	Low water assurance
RMVPLN	Potim	-8.3	96.4	Low water assurance
AUP	Rio das Pedras	-0.1	95.6	Low water assurance
AUP	Cordeirópolis	-0.5	94.2	Low water assurance
RMSP	Osasco	-1	93.8	Low water assurance
RMS	Salto	-0.1	93.7	Low water assurance
RMSP	Carapicuíba	-1.5	93.6	Low water assurance
RMSP	Itaquaquecetuba	-6.4	92.8	Expansion of the production system
RMSP	Taboão da Serra	-0.7	92.0	Low water assurance
RMC	Artur Nogueira	-3.1	91.7	Low water assurance
RMSP	Jandira	-4.8	89.1	Low water assurance
RMC	Santo Antônio de Posse	-1.9	88.4	Low water assurance
RMC	Vinhedo	-0.7	82.4	Low water assurance
AUJ	Várzea Paulista	-11.4	81.9	Low water assurance
URB	Bragança Paulista	-1.2	81.8	Expansion of the production system
AUJ	Louveira	-0.5	81.6	Low water assurance
RMS	Itu	-0.7	80.5	Low water assurance
RMSP	Mauá	-2.4	80.1	Expansion of the production system

Source: Own elaboration

There are municipalities in unfavourable conditions in all regions, except for the RMBS. However, it is worth noting that the RMSP and the RMC together hold the majority of the municipalities (60%). The situation is made worse by climate change projections, which point to longer periods of consecutive dry days throughout the MMP, with more intensity in the MRC and its surroundings.

4 DISCUSSION

The use of land use and land cover data to analyze the history of occupation and identify patterns is an important tool for land management. Lira *et al*. (2012) used it in 3 areas in the state of São Paulo to study the structure of the landscape over time (1960 to 2000) and the implications of changes in biodiversity. On the other hand, this work sought to extract from the coverage use data the indicators of production of ecosystem services on a municipal scale for the MMP.

Water production by the environment is sensitive to different types of land use and cover, and one of the main threats to the RMSP's water sources is the uncontrolled urban occupation in its protected areas (COSTA, 2015; FRACALANZA FREIRE, 2015). According to Carmo *et al*. (2014b), this occupation causes domestic sewage, garbage and the diffuse load of pollution generated in urbanized areas to compromise the quality of raw water and make the water source unfeasible, given the increased cost

of treatment and the threat of reducing the quality of water to be distributed to the population. The impairment of surface-water resources in the Alto Tietê Basin, for example, occurs from the peripheral occupation of the metropolitan area of the RMSP, which occurs not only, but mainly, by low-income settlements (CARMO *et al*., 2014b).

In rural areas, conventional agriculture maximizes food supply, fibre and raw materials, but entails environmental disadvantages such as loss of biodiversity, superficial runoff of water and nutrients, silting of watercourses, emission of greenhouse gases, aquifer contamination, among other problems (POWER, 2010).

In MMP, suppressing natural vegetation due to the expansion of urban occupation and other uses in rural areas reduces the number of ecosystem services offered, such as water production. In addition, the low water assurance and the deficiency in the supply infrastructure registered by the National Water Agency indicate the urgent need for investment in public policies to change the situation.

As seen before, there is an aggravating factor in the identified trend of increasing CDD index values over a 10-year horizon for the entire MMP, whose trend corroborates Chou *et al*. (2014a), which show temperature increase projections all over South America, with different intensities, and the decrease in the volume of precipitation in an intensified way, and, consequently, increase in CDD values for the Southeast region of Brazil.

There are possible actions within the scope of performance of the cities to improve this scenario since the municipalities are responsible for the use and occupation policies in their territories. Regarding land use and land cover, actions to recover degraded areas and restore natural vegetation in areas of permanent preservation can be implanted to increase the regularity of water flows, especially in times of greater criticality. The identification of springs with environmental liabilities, for example, can be provided through data from the Rural Environmental Registry, as proposed by Coutinho *et al*. (2018).

Regarding climate improvement, the 10 steps of the UNISDR campaign to build a resilient city (UNDRR, 2021) can be implemented, focusing on water scarcity as a natural disaster, and the implementation of a municipal climate change adaptation plan under the framework of the Global Covenant of Mayors for Climate & Energy (GCOM, 2021).

On the other hand, one must also emphasize that the mitigation of supply problems in the most critical municipalities and regions of the MMP takes place through the management of the MMP as a whole, especially because the production of water occurs at the scale of hydrographic basins, considering that these extrapolate the limits of the metropolitan regions of the MMP and even the state of SP. Thus, even if the most critical municipalities are more likely to be prioritized, as evidenced in this study, analyses are necessary for planning in the macro-region scale, as indicated by Torres and Jacobi (2020), especially in participatory management arrangements.

Such perspective, concerning participatory management, is corroborated by Folke *et al*. (2005), who suggest adaptive governance, focused on experimentation and learning, which brings together actors to collaborate in collective actions for conflict resolution, as an approach to face crises with these characteristics. In this context, Marques *et al*. (2020) identified discrepancies in the negotiation between civil society and government, in water management, while indicating opportunities for engagement between civil society and academia for effective governance – the study was carried out in some of the MMP municipalities, the metropolitan region of Vale do Paraíba, but the conclusions reflect the conditions found throughout the macro-metropolis.

About water supply, in addition to investing in infrastructure works, policies can be adopted to stimulate the reduction of water demand with the implementation of governance to promote consumer co-responsibility and fiscal incentives.

Given the different land use and land cover profiles of the municipalities in the MMP, the implementation of PES programs is a policy strategy to seek a form of compensation for those with greater capacity to produce ecosystem services compared to those with high demand and production limitations due to their consolidated area predominantly destined for other purposes. The sanctioning of Law 14.119, of 2021, which institutes the National Policy of Payments for Environmental Services (BRASIL, 2021), encourages and supports this type of strategy.

The deployment of water PES associated with the demands of vegetation cover is a potential instrument to assist in the conservation of water resources regarding quality and quantity (LIMA *et al*., 2013). However, it is essential to strengthening the management bodies of the PES, including the training of its members, to ensure the maintenance of conserved areas, regardless of the political changes that may occur in the municipality or state (JARDIM, 2010).

The actions previously listed, as an example at the municipal level, become more efficient as they are transposed to the MMP scale, as they seek to identify common objectives, sharing experiences and results, making municipal decision-makers the key players in adaptive governance.

5 CONCLUSION

The history of land use and land cover transition, the urban supply situational framework and the projections of climate variables and indexes for MMP municipalities have generated public management challenges. These challenges, especially water supply, where there is a growing demand and limited supply of ecosystem services, require actors attentive to the impacts of climate change predicted by different models. The models show an upward trend in temperature, rainfall reduction and greater frequency of consecutive dry day periods. In addition, land use and land cover changes directly affect water production, and despite the MMP having a balanced number of natural areas after three decades, there were significant transitions over the period and municipalities with different profiles regarding the maintenance of areas with greater capacity to produce ecosystem services.

In this context, even municipalities that dominate urban areas, and, consequently, with a smaller rural area for investment in ecological restoration, should guide their policies to the expansion of climate resilience, and actions such as the revitalization of the urban fabric, through the deployment and the restoration of parks and green areas, which contribute to cooling temperature and dampening floods. Investment in nature-based solutions (NbS) and ecosystem-based adaptation (EbA) has advanced in this regard and contributes to the generation of numerous other co-benefits.

The amount of natural area in the municipalities of the MMP is quite variable, both in percentage and in absolute values, and these dynamics affect the provision of ecosystem services. Land use and land cover transitions in the last 30 years culminated in a practically neutral balance in the MMP, however, the transitions occurred, as 53% of the municipalities increased their natural areas, and 47% reduced them.

Concerning urban supply, 58% of the municipalities in the MMP need investment to continue supplying the growing demand. The Metropolitan Regions of São Paulo and Campinas stand out, with most of their municipalities in such conditions. The outcome of transitions to natural coverage areas was positive for the RMC and negative for the RMSP. However, the availability of natural areas for the RMC, in 2018, is lower, with most of its municipalities maintaining less than 20% of their territory with natural coverage, and this characteristic has been observed in a continuous block of municipalities on the Metropolitan Region of Sorocaba and the Urban Agglomeration of Piracicaba.

In addition, the provision of ecosystem services can suffer negative impacts caused by changes in the average temperature, volume and intensity of rainfall and longer dry periods as an effect of climate

change, even given the projection of an intermediate scenario, in which mitigation policies and actions are considered to reduce greenhouse gas emissions.

The provision areas of ecosystem services go beyond the political limits of the municipalities, and, in the case of water production for the MMP, they go beyond their limits, such as the basins that contribute to the Cantareira Supply System. Therefore, there is a need to identify and map the producers and consumers of ecosystem services at the river basins scale, to evidence existing flows.

The mosaic of different profiles of the municipalities of the MMP, built along decades and facing great challenges, especially with water supply, requires actions to identify and recover springs and degraded areas, construction of resilient cities, water supply infrastructure investment, demand management incentives, adaptive governance and implementation of payment programs for environmental services.

The adoption of municipal climate adaptation planning and policies that integrate these issues is urgent, especially for the 20 municipalities in the MMP listed with a natural coverage percentage of less than 20%, with a history of diminishing natural coverage area during the analysis period and with a diagnostic of unfavourable water supply.

Finally, there is a need for discussion on integrated MMP management to equalize municipal differences to improve the capacity of managers to understand the territory, to identify their role in the MMP, its deficiencies and its potential in this new geographic arrangement, which needs policies aimed at sustainable actions.

ACKNOWLEDGEMENTS

This article was elaborated from the research works in the scope of the projects “Environmental Governance in the São Paulo Macrometropolis” (FAPESP 15/03804-9) and “ELOS - Expanding the connections: From dose-response relationships to governance of ecosystem services in the Atlantic Forest” (FAPESP 2018/16781-5). The authors would like to thank the São Paulo Research Foundation - FAPESP (fapesp.br/en) - for supporting these projects.

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Variações no uso e na cobertura da terra na Macrometrópole Paulista e implicações para a resiliência hídrica sob mudanças climáticas

Land use and land cover changes in São Paulo Macro Metropolis and implications for water resilience under climate change

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doi:10.18472/SustDeb.v12n2.2021.32146

Received: 19/06/2020
Accepted: 28/06/2021

ARTICLE – VARIA

RESUMO

A Macrometrópole Paulista (MMP) é um arranjo geográfico que reúne os mais significativos números socioeconômicos brasileiros e enfrenta inúmeros desafios, como a grande pressão sobre os recursos

naturais. Por meio da compilação, espacialização e do cruzamento de dados, este trabalho avaliou séries temporais de uso e ocupação da terra das últimas décadas, a situação do abastecimento de água no meio urbano e dados de projeção climática para a MMP. Foram identificados municípios com perfis distintos: os que apresentam saldos finais positivos e os que apresentam saldos finais negativos com relação à manutenção de suas áreas naturais. Além disso, mais da metade dos municípios da MMP possui baixa garantia hídrica, o que pode ser agravado devido às mudanças climáticas, como previsto em diversos modelos climáticos. A caracterização dos municípios a partir dessas informações permitiu identificar quais deles são os mais vulneráveis, e esses resultados indicam caminhos para ações coordenadas nos níveis locais e regionais para fins de ampliação da resiliência hídrica na macrorregião.

Palavras-chave: Macrometrópole Paulista. Mudanças de uso e ocupação da terra. Serviços ecossistêmicos. Abastecimento urbano.

ABSTRACT

The São Paulo Macro Metropolis (MMP) is a geographical arrangement that combines the most significant Brazilian socioeconomic scores. It also faces numerous challenges, like a heavy pressure on natural resources. Through the compilation, spatialization, and crossing of data, this work aimed to evaluate the land use and land cover data of the last decades, the status of urban water supply, and climate change projections for MMP. Municipalities with different profiles were identified: those with positive and negative balances concerning the maintenance of their natural areas. Furthermore, more than half of MMP's municipalities have low water supply guarantees, whose situation may get worse due to climate change, as predicted by several climate models. The characterization of municipalities based on this information allows the identification of the most vulnerable and these results indicate paths for coordinated actions at local and regional levels for the purpose of expanding water resilience in the macro-region.

Keywords: São Paulo Macro Metropolis. Land use and land cover changes. Ecosystem services. Water supply.

1 INTRODUÇÃO

Em 1950, havia apenas duas "megacidades" – aglomerações urbanas com 10 milhões de habitantes ou mais – no planeta: Nova Iorque e Tóquio (ONU, 2015). Em 2014, 18 países já tinham 28 megacidades, sendo Rio de Janeiro e São Paulo as duas megacidades brasileiras (ONU, 2015). A discussão sobre megacidades chama atenção em países denominados "emergentes", como China, Índia e Brasil (ONU, 2015), pois as populações concentradas nos centros urbanos representam cada vez mais impactos sobre esses próprios centros e seus entornos.

Ao mesmo tempo que nas megacidades há um crescimento guiado por indústrias, comércio, portos e aeroportos, polos de conhecimento e iniciativas de alta complexidade tecnológica, há, também, o crescimento dos problemas comuns às metrópoles, como pobreza, violência, corrupção, desigualdade, deterioração dos edifícios, insalubridade, abastecimento de água, poluição e congestionamentos (THE STATES OF THE WORLD´S CITIES, 2004, 2005). Além disso, como já detectado por Di Giulio *et al*. (2017) e Urbinatti e Ferreira (2019), há grande pressão sobre os recursos naturais e grandes desafios ambientais representados pela perda de serviços ecossistêmicos, alterações do microclima urbano e inadequações nas características de uso da terra, que são potencializados quando megacidades são conurbadas com outras grandes metrópoles. Para lidar com esses problemas, como aponta Graafland (2006), é necessário compreender as cidades além de seus limites políticos, com aproximações que representem suas realidades espaciais, sociais, ambientais e econômicas.

No contexto brasileiro, considera-se a Macrometrópole Paulista (MMP) como um desses aglomerados (Figura 1), em que se inserem, além da megacidade de São Paulo, composta pelos municípios de sua Região Metropolitana, outras cinco Regiões Metropolitanas, duas Aglomerações Urbanas e uma Unidade Regional do estado de São Paulo, representando 21,5% do estado e 20% do patrimônio natural protegido do estado (EMPLASA, 2019).

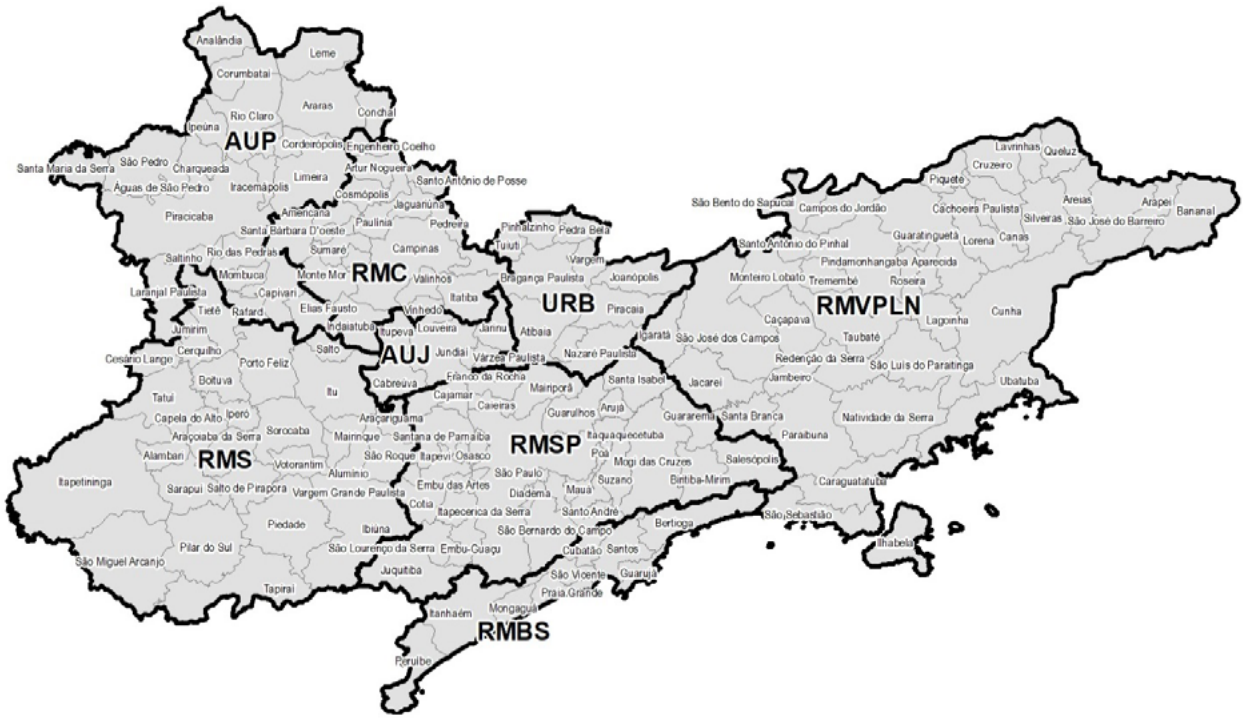

Figura 1 | Municípios da Macrometrópole Paulista agrupados em suas Regiões Metropolitanas, Aglomerações Urbanas e Unidade Regional – Aglomeração Urbana de Jundiaí (AUJ), Aglomeração Urbana de Piracicaba (AUP), Região Metropolitana da Baixada Santista (RMBS), Região Metropolitana de Campinas (RMC), Região Metropolitana de Sorocaba (RMS), Região Metropolitana de São Paulo (RMSP), Região Metropolitana do Vale do Paraíba e Litoral Norte (RMVPLN) e Unidade Regional Bragantina (URB).

Fonte: Elaboração própria.

A dinâmica e as características do crescimento/desenvolvimento/decrescimento da MMP podem determinar maior ou menor propensão para o comprometimento, e até a exaustão, de importantes serviços ecossistêmicos. Estes definidos, de acordo com a Avalição Econômica do Milênio (MEA, 2003), como os benefícios obtidos dos ecossistemas, dos quais os seres humanos são fundamentalmente dependentes e que são categorizados em serviços de provisão, como água, comida e combustível; de regulação, como regulação do clima e purificação da água; culturais, como os benefícios recreativos, estéticos e educacionais; e de suporte, como ciclagem de nutrientes e formação do solo.

Há uma carência de estudos sobre cenários e projeções desse capital natural que possam subsidiar técnica e cientificamente a formulação de políticas públicas para anos futuros. Nesse sentido, este trabalho tem como objetivo avaliar séries temporais de dados de uso e ocupação da terra, buscando identificar, agrupar e ordenar os municípios da MMP em perfis de evolução das áreas de provimento de serviços ecossistêmicos, sobretudo o de produção de água, relacionando-os com a situação de abastecimento de água para o meio urbano e projeções anuais das variáveis climáticas. Com isso, busca-se visualizar as regiões e os municípios da MMP como um todo, apontando os que possuem situação mais crítica com relação aos serviços ecossistêmicos, utilizando como base de análise as coberturas naturais de seu território.

1.1 REVISÃO DE LITERATURA

A área das cidades, em comparação com os limites de seus municípios, geralmente é pequena, mas ainda assim a urbanização é uma atividade humana com potencial de provocar intensas mudanças no uso da terra, com fortes impactos e consequências (ROCKWELL, 2009). A urbanização é um dos processos mais impactantes para o ambiente (CARVALHO; BRAGA, 2001), e o estilo de vida praticado nas grandes cidades do mundo gera alta demanda de energia, poluição, degradação de recursos naturais e a emissão de gases de efeito estufa (FARIA, 2009; HOGAN *et al*., 2001).

Quando associados aos impactos das mudanças climáticas, os problemas urbanos se intensificam: aumento de temperatura, aumento no nível do mar em cidades costeiras, ilhas de calor, inundações, escassez de água e alimentos, acidificação dos oceanos e impactos de eventos extremos (PBMC, 2016). Esses problemas geram novos desafios, como o desabastecimento de água causado por secas prolongadas, a proliferação de vetores de doenças como dengue, zika, chikungunya e leptospirose, e o aumento de doenças respiratórias relacionadas ao clima e/ou à poluição.

Os efeitos da urbanização motivam os estudos atualmente denominados de "nexo água-alimentos-energia", que analisam a interdependência entre esses setores, necessários para garantir o bem-estar humano, a redução da pobreza e a sustentabilidade (FAO, 2014). Alterações em um desses setores podem ter impactos nos outros dois, considerando a alta demanda por seus produtos e o desafio gerencial de equilibrar adequadamente o uso da água para abastecimento humano, irrigação, produção de energia elétrica, entre outros (AHMADI *et al*., 2020; FAO, 2014; SOUSA JÚNIOR, 2018). Na transição demográfica e na transição do consumo urbano de água no Brasil, Carmo *et al.* (2014) apontam a importância da relação entre a dinâmica demográfica e seus desdobramentos para a demanda e o uso da água.

A escassez de água desencadeia situações de conflito em torno dos complexos sistemas de abastecimento. Ao contrário do senso comum, a região metropolitana de São Paulo faz parte de uma área de insuficiente disponibilidade de água limpa, em uma região de complexidade hidrológica (JACOBI; TORRES; GRESSE, 2019). Tal situação suscita o desafio de melhorar a equidade na distribuição de água na metrópole, reforçando o acesso ao sistema público de abastecimento de água, além de garantir o suprimento ao longo do tempo.

O ano de 2014 foi o mais seco na história do estado de São Paulo, desde que os dados começaram a ser registrados, nos anos de 1930. Entre 2013 e 2015, os níveis de água dos principais reservatórios da Região Metropolitana de São Paulo (RMSP) diminuíram drasticamente devido a um fenômeno de estiagem extrema, que afetou mais de 20 milhões de pessoas. Os baixos níveis de precipitação registrados no verão de 2020, diante de reservatórios com volumes muito baixos, prenunciam uma nova crise hídrica, que já se revela nas restrições de geração hidrelétrica (JACOBI; TORRES; GRESSE, 2019).

O aumento da frequência de tais eventos de seca e suas consequências para o provimento de água e energia são reflexos de mudanças climáticas que exigem investimento em políticas de adaptação para a RMSP, conforme apontam Sousa Júnior *et al*. (2016).

As bacias das represas de Billings e Guarapiranga, em São Paulo, são importantes regiões prestadoras de serviços ecossistêmicos, em especial, o de produção de água para abastecimento público. Ainda que protegidas por ordenamento territorial desde a década de 1970 (leis de proteção e recuperação dos mananciais), essas bacias se encontram fortemente pressionadas pelo uso da terra no entorno das represas, não direcionado para a preservação (PMMA SÃO PAULO, 2017).

Segundo Kowarick (2002), as características de uso e ocupação da terra são forçantes que determinam não apenas o crescimento e o desenvolvimento das cidades, mas, também, as consequências e os impactos destes últimos. Como exemplo, o autor aponta as questões de moradia como contribuintes para a determinação do padrão de vida urbano. No caso da cidade de São Paulo, conforme apontam

Leonel *et al*. (2019) e Sampaio e Pereira (2003), parte significativa de sua população ainda não tem moradia ou mora em condições precárias, por falta de serviços de infraestrutura (saneamento, coleta de lixo urbano, entre outros) ou por estar localizada em áreas de risco de desmoronamento, inundação e incêndio, devido a ligações elétricas precárias.

Sampaio e Pereira (2003) já identificavam na Política Nacional de Proteção e Defesa Civil (PNPDEC) e no Plano Diretor Estratégico (PDE) de São Paulo elementos para evitar novas ocupações em áreas de risco. Esses planos também previam a urbanização de áreas carentes e ações para "Equidade e Inclusão Social e Territorial" como forma de reduzir o contraste entre a acumulação e a pobreza.

Por outro lado, Amato-Lourenço *et al*. (2016) apontam que a criação de áreas verdes pode minimizar efeitos da expansão urbana, como a supressão da cobertura vegetal, além de contribuir para a melhoria da qualidade de vida da população. Em São Paulo, projetos como o de criação de 100 parques urbanos (SECRETARIA MUNICIPAL DO VERDE E MEIO AMBIENTE, 2012) e a Reserva da Biosfera do Cinturão Verde (RBCV) buscam arrefecer a pressão gerada pela urbanização sobre os cursos de água e mananciais hídricos, como observam Rodrigues *et al*. (2006).

O patrimônio ambiental, os serviços ecossistêmicos, a proteção dos recursos hídricos por meio do Pagamento por Serviços Ambientais – PSA (PAVANI *et al*., 2020), os cenários de reflorestamento e erosão, a estimativa de áreas de pasto e florestas e as alterações entre essas categorias, todos esses aspectos se interconectam nas análises sobre a MMP. A análise da dinâmica do uso e da cobertura da terra é, portanto, fundamental para uma avaliação dos usos, da dependência e dos impactos sobre o provimento de serviços ecossistêmicos. Sua utilização é propícia para o contexto macrorregional de inserção da MMP. De acordo com Verburg *et al*. (2009), a quantificação das feições específicas e o seu relacionamento com as funções ecossistêmicas fornecem importante base de informações para a elaboração de políticas e planejamento do território.

A governança adaptativa, focada na experimentação e no aprendizado, que reúne atores para colaboração em ações coletivas visando à resolução de conflitos (FOLKE *et al*., 2005), tem sido sugerida para enfrentar contextos como a crise hídrica de 2013-2015. De acordo com Torres e Jacobi (2020), tais questões necessitam de tratativas em escala macrorregional em contexto de gestão participativa. No entanto, há um descompasso na negociação entre a sociedade civil e o poder público, como detectado por Marques *et al*. (2020), os quais, por outro lado, identificam oportunidades de engajamento entre sociedade civil e academia para a governança da água.

2 MÉTODO

A área de estudo deste trabalho, a Macrometrópole Paulista (MMP), abrange 53,4 mil km^2, com 174 municípios (50% da área urbanizada do estado de São Paulo), que representavam 74,7% da população estadual, em 2018, e 81,9% do PIB estadual, em 2016 (EMPLASA, 2019). Dessa população, de acordo com o Censo 2010 (IBGE, 2010), 2,68 milhões de pessoas viviam em setores subnormais (EMPLASA, 2019). A MMP abrange as seguintes regiões metropolitanas: Aglomeração Urbana de Jundiaí (AUJ), Aglomeração Urbana de Piracicaba (AUP), Região Metropolitana da Baixada Santista (RMBS), Região Metropolitana de Campinas (RMC), Região Metropolitana de Sorocaba (RMS), Região Metropolitana de São Paulo (RMSP), Região Metropolitana do Vale do Paraíba e Litoral Norte (RMVPLN) e Unidade Regional Bragantina (URB).

Para apoiar as análises, foram utilizados três conjuntos de dados, os quais foram processados e atribuídos à malha de municípios do recorte da MMP e dispostos no período, conforme mostra a Figura 2.

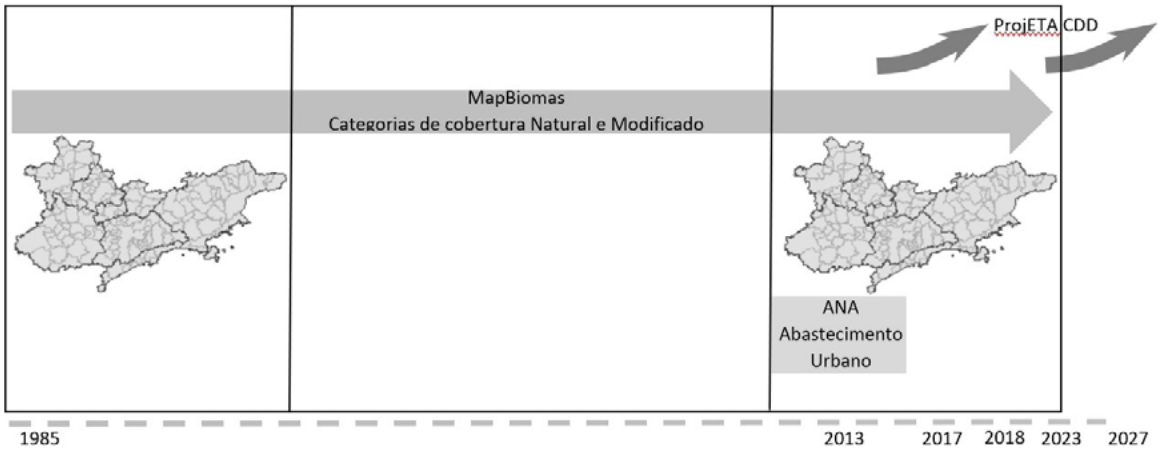

Figura 2 | Diagrama com os dados considerados como suporte para as análises do trabalho: Transições MapBiomas 1985-2018; Abastecimento Urbano do Atlas ANA 2013; Projeção da variável CDD do Projeta nos períodos de 2013 a 2017 e 2023 a 2027.

Fonte: Elaboração própria.

São disponibilizados pelo MapBiomas os dados relacionados ao uso e à cobertura da terra; pelo Cptec/Inpe, os dados relacionados às projeções de variáveis climáticas; e pela Agência Nacional de Águas (ANA), os dados relacionados ao Abastecimento Urbano.

O MapBiomas (PROJETO MAPBIOMAS, 2019) é uma iniciativa multi-institucional que produz e dissemina, sistematicamente, dados de uso e cobertura da terra de todo o território brasileiro, detalhando as transições ocorridas anualmente de 27 categorias, desde o ano de 1985. Os dados de cobertura e transições são disponibilizados em formato *raster*, apropriado para produção de mapas e operações de geoprocessamento, e em formato de planilha eletrônica, com os quantitativos de áreas, agrupados por biomas, estados e municípios.

Para este trabalho, as categorias dos dados *raster* de cobertura da terra foram agrupadas conforme a Tabela 1, exibindo o mapeamento com apenas dois grupos de categorias: Natural e Modificado. O grupo Natural inclui as categorias de ambiente natural preservado, e o grupo Modificado inclui as categorias em que houve modificações antrópicas de cobertura da terra. Esse agrupamento busca distinguir as categorias com maior potencial de fornecimento de serviços ecossistêmicos daqueles com menor potencial, destinados às atividades econômicas convencionais e outras ocupações. É importante ressaltar que as transições entre categorias ocorreram do grupo Natural para Modificado e vice-versa, e, portanto, o incremento de áreas do grupo Natural pode se referir não exatamente às áreas naturais, mas, também, às regiões que, em algum momento, foram destinadas à recuperação e à regeneração.

Tabela 1 | Agrupamento de categorias de uso e cobertura da terra do MapBiomas.

Natural	*Modificado*
Afloramento Rochoso	Agricultura
Apicum	Floresta Plantada
Floresta Natural	Infraestrutura Urbana
Formação Campestre	Mineração
Outra Formação não Florestal	Mosaico de Agricultura ou Pastagem
Praia e Duna	Não Observado
Rio, Lago e Oceano	Outras Áreas não Vegetadas
	Pastagem

Fonte: Elaboração própria

Foram feitos dois ordenamentos considerando valores absolutos em área e em percentual de transições, de forma que foi possível identificar os municípios com maior perda e os com maior ganho de áreas do grupo Natural no período analisado. Assim, identificam-se os municípios com maior ritmo de transições e o *status* atual de cobertura com relação às categorias com maior potencial de oferta de serviços ecossistêmicos.

Com relação aos dados de clima, o Cptec-Inpe utilizou o modelo regional ETA e realizou o *downscaling* dos modelos globais BESM, HadGEM2-ES, MIROC5 e CanESM2, e obteve as projeções de variáveis climáticas com frequência anual, mensal, diária e de 3 horas para a América do Sul para o período de 2006 até 2099 nos cenários RCPs (*Representative Concentration Pathway*) 4.5 e 8.5 (CHOU *et al*., 2014a; CHOU *et al*., 2014b; LYRA *et al*., 2018).

Para este estudo, foi utilizada a variável Número Máximo de Dias Secos Consecutivos no Ano (CDD) das projeções climáticas anuais do modelo ETA HadGEM RCP 4.5, que está disponível com resolução espacial de 5 quilômetros para os estados da Região Sudeste do Brasil na plataforma Projeta (CPTEC/INPE, 2020). Esse índice foi selecionado por ser capaz de indicar períodos de baixa precipitação e condições que favorecem a seca. Esses dados estão divididos temporalmente de 1961 a 2005, período em que representam os resultados do modelo utilizando dados observados, e de 2006 a 2099, período de projeção para os cenários climáticos.

Os dados de abastecimento de água à população encontram-se no Atlas de Abastecimento Urbano da Agência Nacional de Águas (ANA, 2020) e também compõem este trabalho. Nele, cada município brasileiro é classificado da seguinte forma: “abastecimento satisfatório”, em que o município não apresenta criticidade no manancial e nem na infraestrutura de abastecimento; “ampliação do sistema produtor”, em que o município não apresenta problemas de abastecimento, mas há a necessidade de ampliação de unidades do sistema produtor; “baixa garantia hídrica”, em que o sistema de abastecimento do município necessita de novo manancial ou se encontra em condição de racionamento, colapso ou alerta (em 2013); e “sem informação”.

3 RESULTADOS

3.1 ALTERAÇÕES NO USO E NA COBERTURA DA TERRA

Considerando as transições de uso e cobertura identificadas nos dados MapBiomas para o recorte da MMP, houve redução de 0,26% nas categorias do grupo Natural na MMP em todo o período de 1985 a 2018. Apesar de o percentual ser praticamente nulo, isso não significa a inexistência de transições no período, pois as transições das categorias ocorreram nos dois sentidos: do grupo Natural para o grupo Modificado e vice-versa, oscilando ao longo dos anos.

O histórico de transições de uso e cobertura da terra culmina nos dados mais recentes de 2018, que mostram o panorama atual da paisagem, e, por eles, é possível identificar regiões com diferentes características com relação à manutenção de áreas da categoria Natural, como visto na Figura 3, com representação do percentual de área da categoria Natural de cada município.

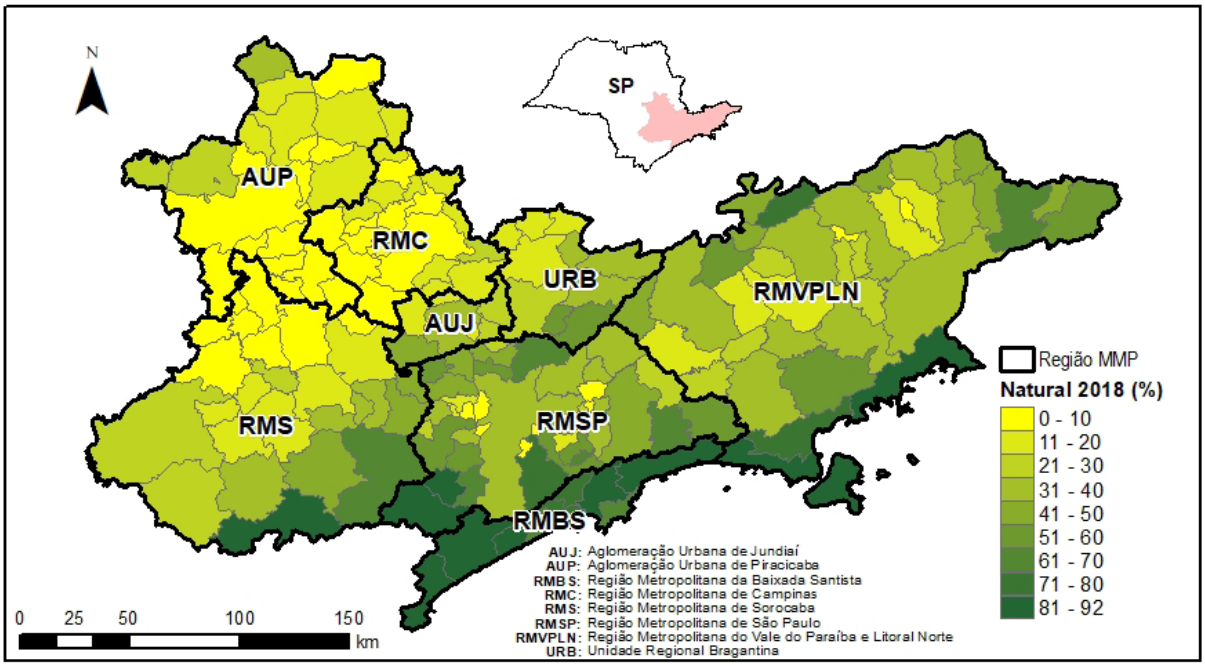

Figura 3 | Municípios da MMP e respectivos percentuais de cobertura Natural em 2018.

Fonte: Elaborado pelos autores a partir de dados do MapBiomas (PROJETO MAPBIOMAS, 2019).

A maioria dos municípios das Regiões Metropolitanas de Campinas e Sorocaba e a Aglomeração Urbana de Piracicaba possui menos de 20% de sua cobertura entre aquelas categorizadas como Natural. Esses municípios formam um bloco contínuo que se expande até a Aglomeração Urbana de Jundiaí e Unidade Regional Bragantina. Por outro lado, há municípios com mais de 80% de cobertura categorizados como Natural, que se concentram na faixa costeira do estado, com destaque para a Região Metropolitana da Baixada Santista, com a maioria de seus municípios com essa característica.

Analisando outros municípios, é possível observar que o percentual do grupo Natural de São Caetano do Sul é de 0,1%, e, por outro lado, 92% do território de Ubatuba são do grupo Natural, e, ainda assim, houve transição de 0,8% do grupo Modificado para Natural. Tal fato reflete parcialmente os resultados encontrados por Farinaci (2012) em pesquisa sobre a intenção de produtores rurais de ampliar áreas de floresta em suas propriedades. Segundo a autora, em municípios como Ubatuba, Monteiro Lobato e São Luiz do Paraitinga, a resposta foi afirmativa, enquanto em municípios como Campinas, Jundiaí e São José dos Campos, a maior parte dos produtores não tem a intenção de aumentar as florestas.

A Figura 4 mostra o histórico dos municípios das regiões da MMP conforme o percentual do saldo final acumulado do período das transições do grupo Natural para o grupo Modificado, ou seja, em 33 anos, o saldo final indica que houve municípios que suprimiram até 18,5% de sua área com transições do grupo Natural para o Modificado, e municípios que incrementaram em até 9,6% de sua área com transições do grupo Modificado para o Natural. Em valores absolutos, há municípios que suprimiram até 55 km² as categorias do grupo Natural e, também, municípios que incrementaram em até 41 km² essas categorias.

Os quantitativos das transições nos municípios foram ordenados considerando-se o saldo final do grupo Natural com relação aos valores absolutos de área e, também, o saldo final do grupo Natural em percentual da área do município. Tanto para a área como para o percentual, foram identificados os cinco municípios da MMP com maior e menor saldo no final do período.

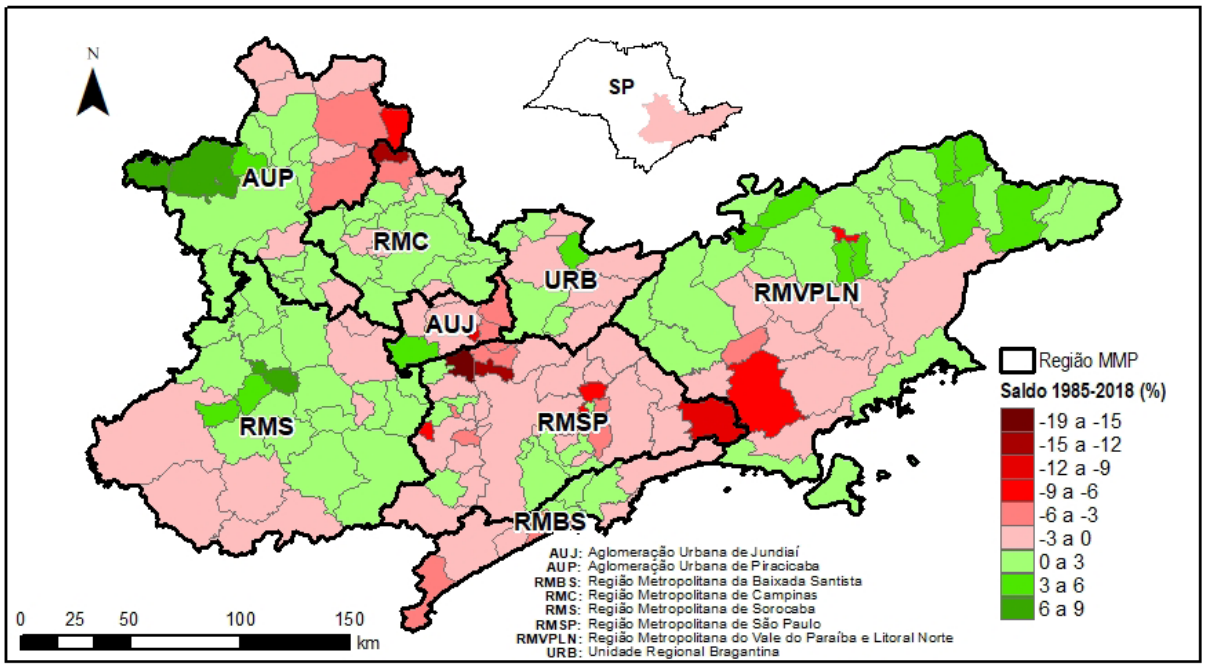

Figura 4 | Mapa com o percentual das transições de cobertura da terra entre 1985 e 2018 na MMP. Tons de vermelho indicam perda de áreas naturais, e tons de verde indicam ganho.

Fonte: Elaborado pelos autores a partir de dados do MapBiomas (PROJETO MAPBIOMAS, 2019).

Conforme o balanço final, mostrado na Tabela 2, as regiões AUP, RMC e RMS, situadas no oeste da MMP, apresentaram percentual positivo com relação às classes de vegetação Natural. Nas demais regiões, o percentual foi negativo, inclusive na RMVPLN, onde a predominância de municípios com saldo positivo na Serra da Mantiqueira e no Litoral Norte não foi suficiente para compensar o decréscimo dos outros municípios.

Tabela 2 | Classificação das regiões conforme o saldo de área da classe de vegetação Natural a partir das transições de categorias no período de 1985 a 2018.

Região	*População (2019)*	*Área (km²)*	*Saldo Natural (km²)*	*Saldo Natural (%)*
Região Metropolitana de São Paulo (RMSP)	21.734.682	7.947	-146	-1,84
Região Metropolitana da Baixada Santista (RMBS)	1.865.397	2.429	-49	-2,04
Aglomeração Urbana de Jundiaí (AUJ)	815.338	1.269	-10	-0,80
Unidade Regional Bragantina (URB)	434.655	2.768	-8	-0,29
Região Metropolitana do Vale do Paraíba e Litoral Norte (RMVPLN)	2.552.610	16.178	-6	-0,04
Região Metropolitana de Campinas (RMC)	3.264.915	3.792	17	0,45
Aglomeração Urbana de Piracicaba (AUP)	1.495.220	7.368	23	0,32
Região Metropolitana de Sorocaba (RMS)	2.143.786	11.611	43	0,37
Macrometrópole Paulista (total)	34.306.603	53.362	-137	-0,26

Fonte: Elaboração própria

Com relação ao percentual de áreas que sofreu transição de Natural para Modificado, os municípios de Cajamar, Caieiras, Engenheiro Coelho, Várzea Paulista e Salesópolis possuem os maiores valores (18,5%, 12,6%, 12,2%, 11,4% e 9,6%, respectivamente). Por outro lado, os maiores saldos finais em percentual de transição de Modificado para Natural foram dos municípios de Iperó, Santa Maria da Serra, São Pedro, Águas de São Pedro e Cabreúva (8,5%, 7,9%, 6,8%, 5,2% e 4,8%, respectivamente).

Quanto ao saldo final, em valores absolutos de áreas que sofreram transição de Natural para Modificado em todo o período, os municípios de Paraibuna, Salesópolis, Cunha, Cajamar e Limeira tiveram os maiores valores (55 km^2, 41 km^2, 25 km^2, 24 km^2 e 23 km^2, respectivamente).

Os municípios de São Pedro, Piracicaba, Santa Maria da Serra, São José do Barreiro e Iperó, por outro lado, tiveram os maiores saldos em valores absolutos de transições das categorias Modificado para Natural (41 km^2, 21 km^2, 20 km^2, 17 km^2 e 14 km^2, respectivamente). Assim, os municípios de Cajamar e Salesópolis destacam-se com os maiores percentuais e valores absolutos de áreas em transições das categorias Natural para Modificado, e os municípios Iperó, Santa Maria da Serra e São Pedro destacam-se com os maiores percentuais e valores absolutos de áreas em transições das categorias Modificado para Natural.

Há, ainda, um grupo de municípios com os menores percentuais de suas áreas nas categorias Natural em 2018. São os municípios de São Caetano do Sul, Hortolândia, Sumaré, Cerquilho e Santa Bárbara d'Oeste, com no máximo 3% de seu território nas categorias Natural. Por outro lado, os municípios de Ubatuba, Ilhabela, Tapiraí, Juquitiba e Bertioga apresentam, em 2018, percentuais de área nas categorias Natural em aproximadamente 90% de seu território.

O município de Cajamar, por sua proximidade com a região metropolitana de São Paulo, possui vários centros logísticos e de distribuição e concentra suas atividades econômicas na extração de madeira e pedra; indústria de alimentos, cosméticos, metalurgia e química; mineração de calcário, além da logística de produtos em geral (MDIC, 2018). As atividades econômicas e a localização geográfica do município de Cajamar ajudam a explicar a diminuição de áreas naturais verificada nos dados.

Iperó, representando o oposto, é o município com maior incremento de áreas naturais e encontra-se na região metropolitana de Sorocaba. Nesse município, está inserida a parte da Flona de Ipanema, onde atividades de educação ambiental e de conscientização da população têm sido implementadas no entorno ao longo do tempo.

Em nível municipal, ainda há problemas para a manutenção de áreas de vegetação na ocasião das discussões dos novos Planos Diretores e Leis de Zoneamento, principalmente em áreas de proteção ambiental de Cerrado. Em São José dos Campos, o Cerrado, que cobria 30% do território municipal, representa atualmente apenas 1% dessa cobertura nativa (CODAZZI, 2019).

3.2 PROJEÇÕES CLIMÁTICAS

Os dados anuais da variável CDD da projeção climática gerados pelo Cptec/Inpe e disponibilizados na Plataforma Projeta foram processados para o recorte da MMP considerando o modelo regional ETA-HadGEM-ES. Esses dados compreendem o período histórico de 1961 a 2005, constituídos a partir de dados observados, e os que compreendem o período de projeção sob o cenário RCP 4.5, de 2006 a 2099.

O índice climático CDD é obtido a partir dos dados da variável Precipitação (Prec) e indica a quantidade de dias consecutivos com precipitação inferior a 1 milímetro no período em que os valores mais altos podem caracterizar condições favoráveis à seca. A média anual histórica do CDD na MMP foi de 20,6 (1961 a 2005), a média do período de 2038 a 2042 de 22,7, e a média dos cinco últimos anos da projeção de 28,1 (final do século XXI). Nota-se que esse índice é crescente de acordo com a observação dessas três médias e é um importante referencial nas questões de abastecimento urbano, entre outras.

Observou-se grande amplitude nesse índice nos períodos de 2013 a 2017 e 2023 a 2027, e a diferença da média de cada período é apresentada na Figura 5. De acordo com a projeção, exceto em alguns pontos no Litoral Norte Paulista, toda a MMP terá uma sequência maior de dias secos no período de 2023 a 2027 (em torno de 2025), considerando o período de 2013 a 2017 (em torno de 2015) como referencial devido à crise hídrica. Além de o índice não ser favorável para toda a MMP na projeção de 10 anos, há uma faixa que inclui a URB, AUJ, RMC e AUP, em que há uma criticidade ainda maior, com extensão dos dias secos em aproximadamente mais um mês.

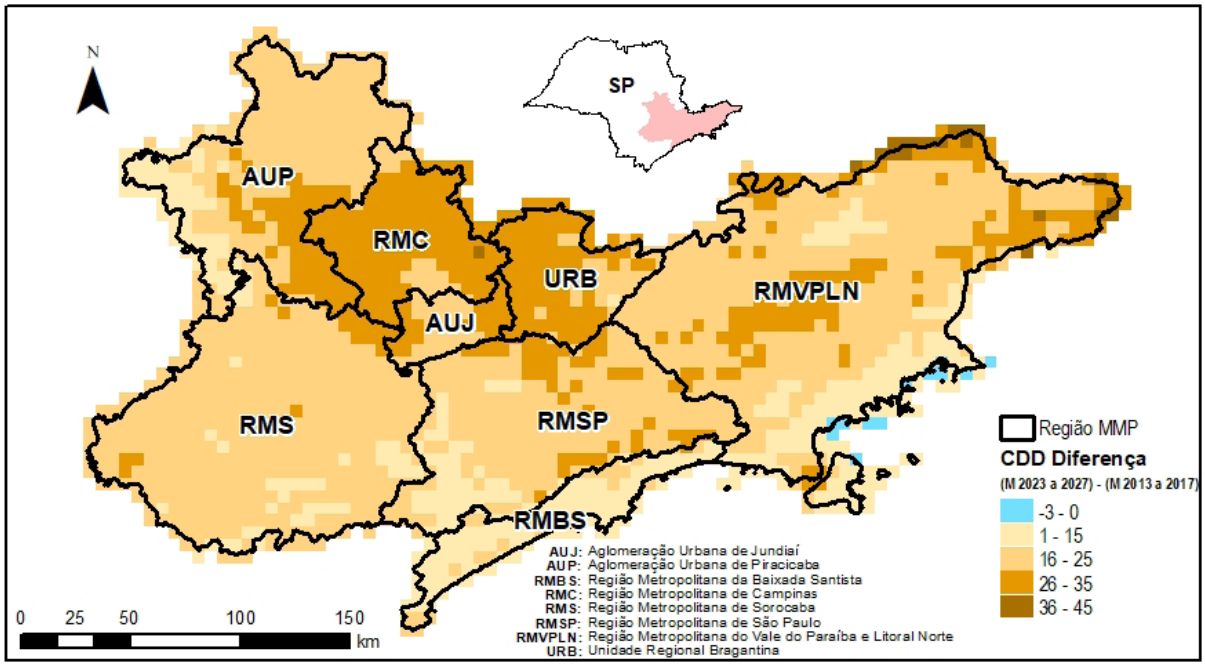

Figura 5 | Mapa da MMP com a representação da diferença das médias do índice CDD dos períodos 2023 a 2027 e 2013 a 2017. Os valores positivos, que ocupam quase integralmente o mapa, indicam que houve aumento do índice com relação aos dois períodos.

Fonte: Elaborado pelos autores a partir de dados Projeta (CPTEC/INPE, 2020).

3.3 ABASTECIMENTO URBANO

Buscar alternativas para garantir a segurança hídrica é um desafio de gestão, principalmente ao considerar os efeitos diretos das mudanças climáticas sobre o volume de precipitação, a demanda crescente por água para abastecimento, uso industrial e irrigação na MMP. Cabe ressaltar que alguns municípios, a exemplo de São Paulo, dependem de mananciais que estão além de seu território.

Conforme o Plano Diretor de Aproveitamento de Recursos Hídricos para a Macrometrópole Paulista, oito Unidades de Gerenciamento de Recursos Hídricos são compreendidas pela MMP: Paraíba do Sul, Litoral Norte, Piracicaba/Capivari/Jundiaí, Alto Tietê, Baixada Santista, Mogi Guaçu, Tietê/Sorocaba e Ribeira de Iguape e Litoral Sul.

Os dados da situação do abastecimento dos municípios do Atlas de Abastecimento Urbano para o recorte territorial da MMP estão representados na Figura 6, que mostra que 58% dos municípios da MMP necessitam de investimento nessa área e estão na situação de baixa garantia hídrica ou necessitam de ampliação do sistema produtor.

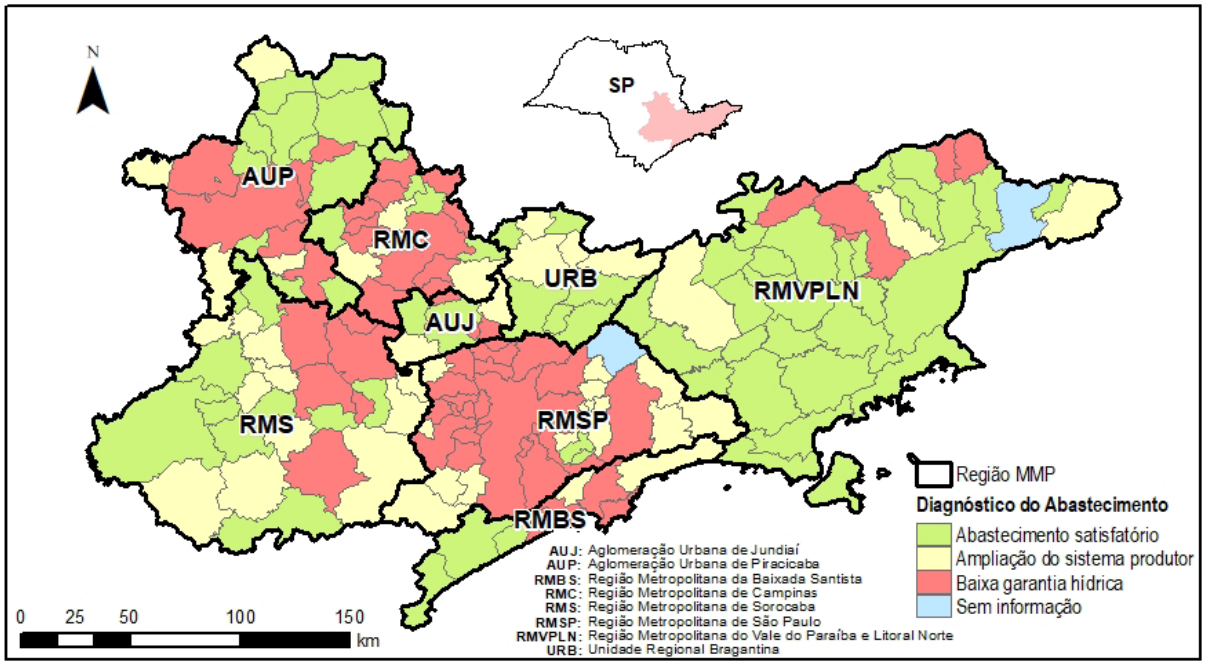

Figura 6 | Mapa com a qualificação do abastecimento hídrico na MMP, conforme o Atlas de Abastecimento Urbano.

Fonte: Elaborado pelos autores a partir de dados do Atlas de Abastecimento Urbano (ANA, 2020).

O mapa indica que em todas as regiões da MMP há municípios com baixa garantia hídrica, exceto a Unidade Regional Bragantina, e que nas duas regiões mais populosas, as Regiões Metropolitanas de São Paulo e de Campinas, a maior parte de seus municípios está nessa situação. É importante salientar que as áreas de contribuição dos sistemas de abastecimento estão além dos limites municipais, das regiões metropolitanas e até mesmo da MMP, como é o caso do Sistema Cantareira de Abastecimento, com áreas a montante no estado de Minas Gerais. Dessa forma, o suprimento de água à população, proveniente dos serviços ecossistêmicos, tem origem em outros municípios adjacentes.

3.4 MUNICÍPIOS CRÍTICOS

A partir da combinação das três informações compiladas e processadas, considerando os diferentes perfis dos municípios da MMP com relação ao histórico de alteração de uso e cobertura da terra, suas áreas naturais atuais com potencial de produção de serviços ecossistêmicos e a situação de abastecimento urbano, foram identificados 20 municípios cujos contextos são mais desfavoráveis (Tabela 3).

Trata-se de municípios que apresentam menos de 20% de seu território com cobertura natural, possuem um saldo negativo com relação à manutenção de áreas naturais e têm um diagnóstico que indica baixa garantia hídrica ou que necessita de ampliação do sistema produtor de água.

Tabela 3 | Municípios da MMP com características desfavoráveis com relação ao fornecimento de serviços ecossistêmicos de produção de água e com necessidade de investimento nos sistemas de abastecimento (ordenados decrescentemente pelo percentual de Área Não Natural em 2018).

Região	*Município*	*Área Natural Convertida (%)*	*Área Não Natural em 2018 (%)*	*Diagnóstico do Abastecimento*
RMSP	São Caetano do Sul	-0.3	99.9	Baixa garantia hídrica
RMC	Hortolândia	-0.7	98.6	Ampliação do sistema produtor
RMC	Sumaré	-0.2	97.3	Baixa garantia hídrica
RMVPLN	Potim	-8.3	96.4	Baixa garantia hídrica
AUP	Rio das Pedras	-0.1	95.6	Baixa garantia hídrica
AUP	Cordeirópolis	-0.5	94.2	Baixa garantia hídrica
RMSP	Osasco	-1	93.8	Baixa garantia hídrica
RMS	Salto	-0.1	93.7	Baixa garantia hídrica
RMSP	Carapicuíba	-1.5	93.6	Baixa garantia hídrica
RMSP	Itaquaquecetuba	-6.4	92.8	Ampliação do sistema produtor
RMSP	Taboão da Serra	-0.7	92.0	Baixa garantia hídrica
RMC	Artur Nogueira	-3.1	91.7	Baixa garantia hídrica
RMSP	Jandira	-4.8	89.1	Baixa garantia hídrica
RMC	Santo Antônio de Posse	-1.9	88.4	Baixa garantia hídrica
RMC	Vinhedo	-0.7	82.4	Baixa garantia hídrica
AUJ	Várzea Paulista	-11.4	81.9	Baixa garantia hídrica
URB	Bragança Paulista	-1.2	81.8	Ampliação do sistema produtor
AUJ	Louveira	-0.5	81.6	Baixa garantia hídrica
RMS	Itu	-0.7	80.5	Baixa garantia hídrica
RMSP	Mauá	-2.4	80.1	Ampliação do sistema produtor

Fonte: Elaboração própria

Há municípios em condição desfavorável em todas as regiões, exceto na RMBS. No entanto, cabe observar que a RMSP e a RMC juntas detêm a maioria dos municípios (60%). A situação é agravada diante das projeções de alterações climáticas, que apontam para períodos mais longos de dias secos consecutivos em toda a MMP, com mais intensidade na RMC e imediações.

4 DISCUSSÃO

A utilização de dados de uso e cobertura da terra para análise do histórico de ocupação e identificação de padrões constitui uma ferramenta importante para a gestão do território. Lira *et al*. (2012) a utilizaram em três áreas no estado de São Paulo para estudar a estrutura da paisagem ao longo do tempo (1960 a 2000) e as implicações das alterações na biodiversidade. Por outro lado, este trabalho buscou extrair dos dados de uso de cobertura os indicativos de produção de serviços ecossistêmicos em um recorte municipal para a MMP.

A produção de água pelo ambiente é sensível aos diferentes tipos de uso e cobertura da terra, e uma das principais ameaças aos mananciais da RMSP é a ocupação urbana descontrolada em suas áreas de proteção (FRACALANZA FREIRE, 2015; COSTA, 2015). Segundo Carmo *et al.* (2014b), essa ocupação faz com que o esgoto doméstico, o lixo e a carga difusa de poluição gerada nas áreas urbanizadas acarretem o comprometimento da qualidade da água bruta e a possível inviabilização de uso do manancial, dado o aumento do custo do tratamento e, inclusive, a ameaça de redução da qualidade da água a ser

distribuída para a população. O comprometimento dos mananciais de superfície da Bacia do Alto Tietê, por exemplo, ocorre a partir da ocupação periférica da mancha metropolitana da RMSP, que ocorre não só, mas principalmente, por assentamentos de baixa renda (CARMO *et al*., 2014b).

Na área rural, a agricultura convencional maximiza a provisão de alimentos, fibras e matérias-primas, mas acarreta desserviços ambientais como perda de biodiversidade, escoamento superficial de água e nutrientes, assoreamento de cursos hídricos, emissão de gases de efeito estufa, contaminação de aquíferos, entre outros problemas (POWER, 2010).

Na MMP, a supressão de vegetação natural devido à expansão da ocupação urbana e outros usos na área rural diminui a quantidade ofertada dos serviços ecossistêmicos como a produção de água. Além disso, a baixa garantia hídrica e a deficiência na infraestrutura de abastecimento registradas pela Agência Nacional de Águas indicam a premente necessidade de investimento em políticas públicas no sentido de reverter o quadro.

Como visto, há o agravante da tendência identificada de aumento dos valores do índice CDD em um horizonte de 10 anos para toda a MMP, cuja tendência corrobora Chou *et al*. (2014a), que mostram projeções de aumento da temperatura para toda a América do Sul, com diferentes intensidades, e o decréscimo do volume de precipitação de forma intensificada, e, consequentemente, o aumento dos valores CDD para a Região Sudeste do Brasil.

Há ações possíveis no escopo de atuação dos municípios para melhorar esse cenário, uma vez que são as municipalidades as responsáveis pelas políticas de uso e ocupação em seus territórios. Com relação ao uso e à cobertura da terra, podem ser implantadas ações de recuperação de áreas degradadas e restabelecimento de vegetação natural em áreas de preservação permanente, a fim de aumentar a regularidade dos fluxos hídricos, especialmente em momentos de maior criticidade. A identificação das nascentes com passivo ambiental, por exemplo, pode ser feita por meio dos dados do Cadastro Ambiental Rural, como propõem Coutinho *et al*. (2018).

No que diz respeito à melhoria do clima, podem ser implementados os dez passos da campanha da UNISDR para a construção de uma cidade resiliente (UNDRR, 2021), com foco na escassez hídrica como desastre natural, e a implementação de um plano municipal de adaptação às mudanças climáticas com o arcabouço do Pacto Global de Prefeitos pelo Clima e a Energia (GCOM, 2021).

Por outro lado, há que se ressaltar que a mitigação de problemas de abastecimento nos municípios e regiões da MMP mais críticos se dá por meio da gestão da MMP como um todo, sobretudo pelo fato de a produção de água ocorrer na escala de bacias hidrográficas, tendo em vista que essas extrapolam os limites das regiões metropolitanas da MMP e até mesmo do estado de São Paulo. Assim, mesmo que se priorizem os municípios mais críticos, evidenciados neste trabalho, são necessárias análises para planejamento na escala de macrorregião, como indicam Torres e Jacobi (2020), especialmente em arranjos de gestão participativa.

Tal visão, com relação à gestão participativa, é corroborada por Folke *et al*. (2005), os quais sugerem a governança adaptativa, focada na experimentação e no aprendizado, que reúne atores para colaboração em ações coletivas visando à resolução de conflitos, como abordagem para o enfrentamento de crises com essas características. Nesse contexto, Marques *et al*. (2020) identificaram descompassos na negociação entre a sociedade civil e o poder público, na gestão das águas, ao mesmo tempo que indicam oportunidades de engajamento entre sociedade civil e academia para efetiva governança – o estudo foi realizado em uma parcela de municípios da MMP, da região metropolitana do Vale do Paraíba, mas as conclusões refletem condições encontradas em toda a macrometrópole.

Com relação ao abastecimento de água, além do investimento em obras de infraestrutura, podem-se adotar políticas que estimulem a redução da demanda por água com a implementação de governança para promover a corresponsabilização dos consumidores e incentivos fiscais.

Diante dos diferentes perfis de uso e cobertura da terra dos municípios da MMP, a implementação de programas de Pagamentos por Serviços Ambientais (PSA) é uma estratégia de política para buscar uma forma de compensação para aqueles com maior capacidade de produção de serviços ecossistêmicos em relação aos que possuem alta demanda e limitações produtivas devido à sua área consolidada predominantemente destinada a outros fins. O sancionamento da Lei 14.119, de 2021, que institui a Política Nacional de Pagamentos por Serviços Ambientais (BRASIL, 2021), estimula e ampara esse tipo de estratégia.

A implantação de PSA hídrico associada às demandas da cobertura vegetal é um instrumento potencial de auxílio à conservação dos recursos hídricos em qualidade e quantidade (LIMA *et al*., 2013). Todavia, é fundamental o fortalecimento dos órgãos gestores do PSA, incluindo a capacitação de seus membros, de forma a garantir a manutenção das áreas conservadas, independentemente das mudanças políticas que venham a ocorrer no município ou estado (JARDIM, 2010).

As ações elencadas anteriormente, como exemplo no nível municipal, tornam-se mais eficientes quando transpostas para a escala da MMP, ao buscarem a identificação de objetivos comuns, o compartilhamento de experiências e os resultados, tornando os decisores municipais os principais atores de uma governança adaptativa.

5 CONCLUSÃO

O histórico de transição de uso e cobertura da terra, o retrato situacional do abastecimento urbano e as projeções de variáveis e índices climáticos para os municípios da MMP geram desafios de gestão pública. Esses desafios, sobretudo o de abastecimento de água, onde se tem uma demanda crescente e limitação das áreas fornecedoras dos serviços ecossistêmicos, requerem atores atentos aos impactos das mudanças climáticas previstos por diferentes modelos. Os modelos apontam tendência de aumento da temperatura, diminuição da precipitação pluviométrica e maior frequência de períodos de dias secos consecutivos. Além disso, as alterações de uso e cobertura da terra afetam diretamente a produção de água, e, apesar da MMP ter um saldo equilibrado de áreas naturais após três décadas, houve significativas transições ao longo do período e municípios com perfis distintos com relação à manutenção de áreas com maior capacidade de produção de serviços ecossistêmicos.

Nesse contexto, mesmo municípios com domínio de áreas urbanas, e, consequentemente, com menor área rural para investimento em restauração ecológica, deveriam orientar suas políticas para a ampliação da resiliência climática e ações como a revitalização do tecido urbano, por meio da implantação e da restauração de parques e áreas verdes, os quais contribuem para o arrefecimento da temperatura e para o amortecimento de inundações. O investimento em soluções baseadas na natureza (SBN) e em adaptação baseada em ecossistemas (EBA) avança nesse sentido e contribui para a geração de inúmeros outros cobenefícios.

A quantidade de área natural nos municípios da MMP é bastante variável, tanto em percentual quanto em valores absolutos, e essa dinâmica afeta o provimento de serviços ecossistêmicos. As transições de uso e cobertura da terra nos últimos 30 anos culminaram em um saldo praticamente neutro na MMP, no entanto, as transições ocorreram, pois 53% dos municípios incrementaram suas áreas naturais, e 47% as diminuíram.

No tocante ao abastecimento urbano, 58% dos municípios da MMP necessitam de investimento para continuar mantendo o fornecimento à crescente demanda. Ressaltam-se as Regiões Metropolitanas de São Paulo e de Campinas, com a maior parte de seus municípios nessa condição. O saldo de transições para áreas de cobertura natural foi positivo para a RMC e negativo para a RMSP. No entanto, a disponibilidade de áreas naturais para a RMC, em 2018, é menor, com a maior parte de seus municípios mantendo menos de 20% de seu território com cobertura natural, e essa característica é observada em um bloco contínuo de municípios sobre a Região Metropolitana de Sorocaba e a Aglomeração Urbana de Piracicaba.

Além disso, a oferta de serviços ecossistêmicos pode sofrer impactos negativos provocados por alterações na média da temperatura, no volume e na intensidade das chuvas e maiores períodos secos como efeito das mudanças climáticas, mesmo tendo em vista a projeção de um cenário intermediário, em que são consideradas políticas e ações mitigatórias para diminuição de emissões de gases de efeito estufa.

As áreas de provisão de serviços ecossistêmicos extrapolam os limites políticos dos municípios, e, no caso da produção de água para a MMP, extrapolam seus próprios limites, a exemplo das bacias contribuintes do Sistema Cantareira de Abastecimento. Portanto, há necessidade de identificar e mapear os produtores e os consumidores de serviços ecossistêmicos na escala das bacias hidrográficas, a fim de evidenciar os fluxos existentes.

O mosaico de distintos perfis dos municípios da MMP, construído em décadas e com grandes desafios, sobretudo com relação ao abastecimento de água, exige ações de identificação e recuperação de nascentes e áreas degradadas, construção de cidades resilientes, investimento em infraestrutura de abastecimento, estímulos à gestão da demanda, governança adaptativa e implementação de programas de pagamentos de serviços ambientais.

A adoção de políticas e planos municipais de adaptação climática que incorporem essas questões é urgente, sobretudo para os 20 municípios da MMP elencados com percentual de cobertura natural inferior a 20%, com histórico de diminuição de área de cobertura natural no período de análise e com diagnóstico de abastecimento de água desfavorável.

Enfim, é evidente a necessidade de debate em torno de uma gestão integrada da MMP e que busque equalizar as diferenças municipais a fim de melhorar a capacidade dos gestores para compreender o território, identificar seu protagonismo na MMP, suas deficiências e seus potenciais nesse novo arranjo geográfico, que necessita de políticas direcionadas a ações sustentáveis.

AGRADECIMENTOS

Este artigo foi elaborado a partir dos trabalhos de pesquisa no âmbito dos projetos “Governança Ambiental na Macrometrópole Paulista” (FAPESP 15 / 03804-9) e “ELOS - Ampliando as conexões: das relações dose-resposta à governança de serviços ecossistêmicos em a Mata Atlântica” (FAPESP 2018 / 16781-5). Os autores agradecem à Fundação de Amparo à Pesquisa do Estado de São Paulo - FAPESP (fapesp.br/en) - pelo apoio a esses projetos.

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Assessment of photovoltaic generation, supply, and sustainability: a case study of municipalities in São Paulo state

Análise de potencial de geração e suprimento fotovoltaicos e sustentabilidade: estudo de caso de municípios do estado de São Paulo

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doi:10.18472/SustDeb.v12n2.2021.37015

Received: 23/03/2021
Accepted: 28/06/2021

ARTICLE – VARIA

ABSTRACT

Energy consumption has been increasing together with population growth and the consequences for energy production widely generate discussions under the aspect of environmental outcome and supply reliability and quality. This paper proposes a methodology that allows the estimation of the potential for cities to be more independent in terms of centralized generation and distribution of electricity considering photovoltaic sources. Sustainability and environmental performance are also discussed. The methodology aims to assess some municipalities in the São Paulo state. The results showed high potential for photovoltaic supply in those municipalities under the considered conditions indicating the possibility for structuring a decentralized generation model where cities would be more independent in electricity supply. Implementing the required photovoltaic systems would return the energy consumed during their life cycle in a relatively short period compared to their expected lifetime.

Keywords: Sustainable energy. Photovoltaic generation. Sustainability. Distributed generation. Modelling.

RESUMO

O consumo de energia tem aumentado com o crescimento populacional, e os impactos causados em função da geração de energia vêm sendo discutidos sob o ponto de vista de suas consequências ambientais, bem como a qualidade e a confiabilidade no fornecimento. Este trabalho tem como objetivo desenvolver uma metodologia que permita a análise da viabilidade de uma maior independência das

cidades em relação à geração centralizada, por meio do estudo do potencial de geração distribuída e suprimento do consumo de energia elétrica pela fonte fotovoltaica. A sustentabilidade e a performance ambiental também são abordadas. São avaliadas algumas cidades do interior de São Paulo e os resultados mostram que há grande potencial de suprimento fotovoltaico sob determinadas condições, indicando a possibilidade de uma maior independência da geração centralizada. Observou-se que os sistemas fotovoltaicos necessários retornariam a energia consumida em seu ciclo de vida em um período de tempo relativamente pequeno.

Palavras-chave: Energia sustentável. Geração fotovoltaica. Sustentabilidade. Geração distribuída. Modelagem.

1 INTRODUCTION

In 2018, global economic growth of 3.7% was observed in comparison with 2017, resulting in a 2.3% increase in energy demand and a 1.7% increase in carbon dioxide (CO_2) emissions, associated with the use of fossil fuels as a primary energy source (IEA, 2018, p. 4). To reduce the impacts of fossil fuel energy generation caused by gas emissions, renewable and sustainable sources have been widely considered to decrease environmental consequences. Those sources represented 26% of all electricity generated worldwide in 2018 when increases in the installed capacity of renewable energy were higher than increases in the installed capacity of fossil and nuclear fuels for the fourth year in a row (REN21, 2019, p. 29).

In the Brazilian scenario, 64.08% of the electric energy matrix comes from hydro-power plants, 25.40% from thermoelectric plants, 9.06% from wind generators, and 1.46% from photovoltaic (PV) solar panels (BIG, 2019). Those numbers show that, besides using hydroelectric power plants, other renewable sources are also being used.

Brazil has a great PV generation potential due to its geographic localization and climatic characteristics, and an increase in PV power generation has been noticed in the last few years. In 2018, Brazilian PV energy generation was approximately 298 thousand toe[1], while in 2017 it was approximately 72 thousand toe, representing an increase of 316.2% (BRASIL, 2019, p. 19).

This work proposes a methodology that allows the estimation of the potential for cities to be more independent in terms of centralized generation and distribution of electricity considering photovoltaic sources. The analysis is performed considering the electric power generation and potential supply of PV energy at the municipal level, to decrease the dependency on the centralized generation. The methodology also takes into account the sun's daily path, the available roof area, and different orientations of the PV module, to simulate residential roof installation.

The calculation of PV potential takes into account a hierarchical methodology that considers the following three levels: physical potential, geographical potential, and technical potential (IZQUIERDO; RODRIGUES; FUEYO, 2008, p. 931). The physical potential is the total energy from the Sun that reaches the studied area; geographical potential consists of the locations where the energy will be captured – residential rooftops, and the technical potential include the technical features of energy conversion equipment for electricity generation and PV module orientation. This approach is addressed in the studies by Assouline, Mohajeri and Scartezzini (2017), Martín, Domínguez and Amador (2015), Nero *et al.* (2020) and Sun *et al.* (2013).The next section gives detailed definitions of the parameters and how they are used for analysis.

2 METHODOLOGY

PV generation depends directly on solar radiation, that is, the amount of incident energy per unit area of a surface (KALOGIROU, 2014, p. 20). This data has been considered as the physical potential for PV generation and is made available by some institutional websites, such as the websites from the National Institute of Meteorology (INMET) and the National Institute for Space Research (Inpe), through the Sistema de National Environmental Database System (Sonda), the Reference Center for Solar and Wind Energy Sergio de S. Brito (Crecesb), and the Inpe's Brazilian Atlas of Solar Energy – see Pereira *et al.* (2017). These data come from automatic measurement stations, which include mainly data from environmental parameters, as well as data generated through mathematical models, for several locations in Brazil. The websites can be accessed through the Crecesb (2020), Inmet (2019), and Inpe (2019).

Pereira *et al.* (2017, p. 35) provided data from statistical models obtained from analysis of the Brazilian solar radiation temporal series made available by the Inmet (2019) and Inpe (2019). Solar radiation estimates are made available by the Crecesb (2020) in a database that was built using satellite imagery and data from a period of 17 years (PEREIRA *et al.*, 2017).

PV generation potential can be evaluated through the following other parameters, besides solar radiation:

- PV module orientation, which is part of the technical potential for PV generation, depends on the surface tilt angle (β) and the angle between the normal to the module's surface in the horizontal plane and the true North, known as Surface Azimuth Angle (Z_S) (KALOGIROU, 2014, p. 63);

- the Sun's daily path during the day, according to the location coordinates of interest (KALOGIROU, 2014, p. 60);

- total available area for PV module installation and the efficiency of PV conversion, which been considered as the geographical potential for PV generation.

The parameters for estimating PV generation and supply, as well as the methodology used, will be defined as follows.

2.1 MODULE ORIENTATION

The PV module orientation is evaluated according to the surface tilt angle (β) and the angle between the normal to the module's surface in the horizontal plane and the true North, known as Surface Azimuth Angle (Z_S) (KALOGIROU, 2014, p. 63). The surface tilt angle (β) has its origin in the horizontal plane containing the module and is illustrated in Figure 1(a).

In the present study, it will be assumed to have the same latitude value from the place of interest, taking into account that this would be the optimum tilt angle for achieving the highest mean solar radiation along the year (TOLMASQUIM, 2016, p. 326).

The Surface Azimuth Angle (Z_S) describes the module rotation around the horizontal plane normal direction. The angle is formed by the normal to the module's surface in the horizontal plane and the true North, which is considered as the origin. Westwards is designated as the positive direction. The parameters are shown in Figure 1(a).

2.2 SUN'S DAILY PATH

The Sun's daily path was modelled according to the parameters mentioned as follows in a three-dimensional representation. Those parameters are angles – α and Z –, which have been adapted to the spherical system of coordinates (STEWART, 2015, p. 927) and are shown in Figure 1(b).

The α angle, defined as the solar altitude angle, is given by (KALOGIROU, 2014, p. 60)

$$\sin(\alpha) = \sin(L)\sin(\delta) + \cos(L)\cos(\delta)\cos(h) \qquad (1)$$

where:

- L s the latitude, with locations in the Northern hemisphere considered as positive values and those in the Southern hemisphere considered as negative values;

- δ is the solar declination, defined as the angle between the equatorial and ecliptic planes. The ecliptic plane is the one containing Earth in its orbit;

- h is the hour angle, defined as the angle that Earth would have to turn for its centre (point O), the location of interest (point P), and the centre of the sun to be contained in a unique plan in a given day hour, as shown in Figure 1(c). The same figure also shows the L, δ and h parameters, which are functions of latitude, longitude, and time of the year, being related to solar declination (δ) (KALOGIROU, 2014, p. 56).

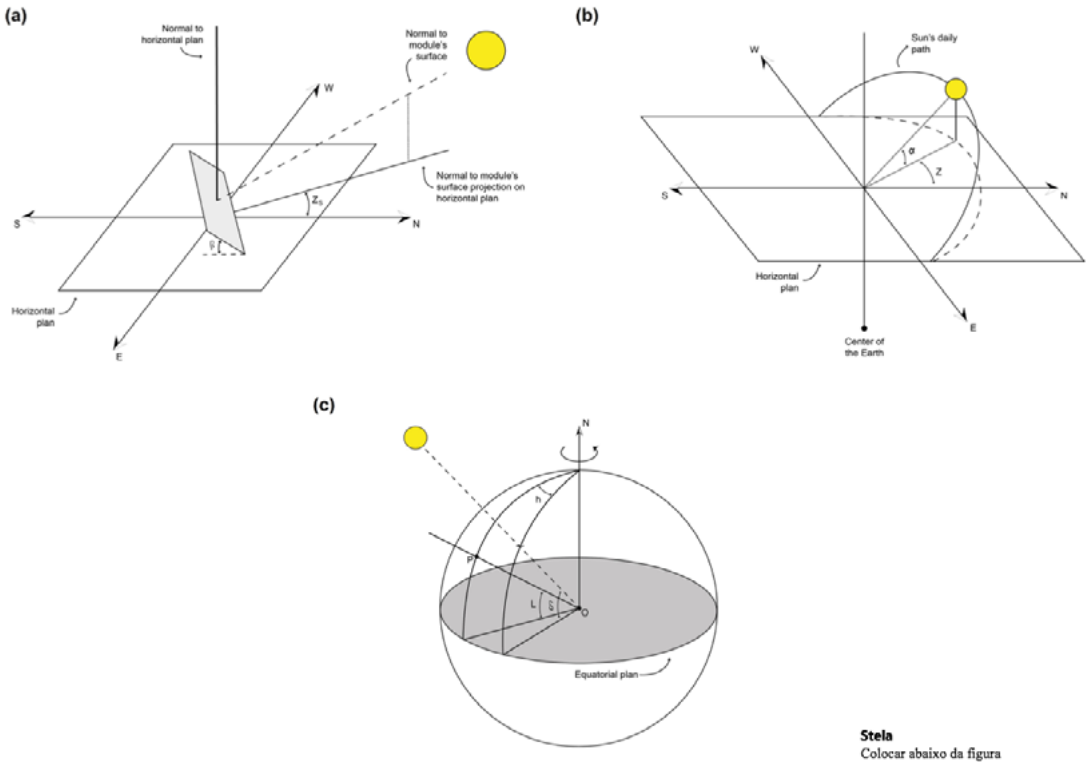

Figure 1 | (a) Parameters β and, Z_S tilt and azimuth surface angles, respectively. (b) Angles α and Z, which describes the Sun's daily path. (c) Solar parameters L, δ and h.

Source: Own elaboration, based on Kalogirou (2014, p. 60).

Solar declination (δ) ranges according to the relative position of the Earth to the Sun. Thus, it ranges according to the period of the year. According to (KALOGIROU, 2014, p. 60):

$$\delta = 23.45 \sin\left[\frac{360}{365}(284+N)\right] \quad (2)$$

where N is the Julian day of the year.

In this study, the PV potential has been obtained for each month of the year using the average day length in a month, as shown in Table 1.

Solar altitude angle (α) is a function of the hour angle (h), which ranges according to the local standard time – the local clock time. The hour angle for a certain location is given by (KALOGIROU, 2014, p. 59)

$$h = 15(AST - 12) \quad (3)$$

where AST is the apparent solar time, based on the Sun's angular motion in the sky. The solar noon occurs when the Sun crosses the observer's meridian. The parameter h is negative for morning hours, positive for afternoon hours and is zero at the solar noon, when $AST = 12$.

Table 1 | *Average Julian day, with respective date and number.*

Month	*Average day*	
	Date	*Number*
January	17	17
February	16	47
March	16	75
April	15	105
May	15	135
June	11	162
July	17	198
August	16	228
September	15	258
October	15	288
November	14	318
December	10	344

Source: Data from Kalogirou (2014, p. 58).

AST is based on other factors, including local standard time, according to the equation (KALOGIROU, 2014, p. 53)

$$AST = LST + ET \pm 4[SL + LL] \quad (4)$$

where

- LST is the local standard time, that is, the local clock time;
- ET is the equation of time;
- SL is the standard longitude, that is, the longitude of the local timezone;
- LL is the local longitude.

The sign of the third member of the equation is negative (-) if the location is West of Greenwich and positive (+) if otherwise (KALOGIROU, 2014, p. 53).

Therefore AST and h change according to LST. The values of LST of the municipalities studied were obtained using the respective sunrise times (h_{SR}), sunset times (h_{SS}) and day length (DL) according to the following expressions (KALOGIROU, 2014, p. 61)

$$\cos(h_{SR}) = \tan(L)\tan(\delta) \qquad (5)$$

$$DL = \frac{2}{15}\cos^{-1}[-\tan(L)\tan(\delta)] \qquad (6)$$

and

$$\cos(h_{SS}) = h_{SR} + DL \qquad (7)$$

The apparent solar time (AST) is also influenced by the equation of time (ET), as shown in equation (4), which considers the natural variation of the 24-hour mean day length. Thus, ET is a correction factor, given in minutes, for the day length of day throughout the year, given by

$$ET = 9.87\sin(2B) - 7.53\cos(2B) - 1.5\sin(B) \qquad (8)$$

where B depends on the Julian day of the year (N):

$$B = (N - 81)\frac{360}{364} \qquad (9)$$

With the parameters h_{SR}, h_{SS} and DL, LST, AST and h values for each minute in the days, sunlight periods can be calculated and with equation (1) the values of solar altitude angle (α) for each minute of the average days can be obtained for a given municipality.

The solar azimuth angle (Z), the second parameter that defines the Sun's daily path shown in Figure 1(b), has its origin in the true North with positive values westwards, being obtained using (KALOGIROU, 2014, p. 60):

$$\sin(Z)=\frac{\cos(\delta)\sin(h)}{\cos(\alpha)} \qquad (10)$$

provided that

$$\cos(h)>\frac{\tan(\delta)}{\tan(L)} \cdot$$

Otherwise, the Sun is in the East-West plane in true South and

$$Z=-\pi+|Z|$$

for morning hours ($h<0$) and

$$Z=Z-\pi$$

for afternoon hours ($h>0$).

2.3 AVAILABLE AREA AND CONVERSION EFFICIENCY

In the present study, the available area for PV module installation has been considered as the estimated roof area of the location of interest. The estimation process is described in this section.

The roof area was estimated through digital image processing (DIP) using Matlab (MATLAB, 2010), and the image samples were obtained from Google Earth Pro. Figure 2 shows one of the images used, on the left, and the result of the segmentation process on the right.

The images were acquired maintaining the original parameters of image resolution, tilt, and viewpoint's distance, with an image resolution of 4800 x 2220 pixels and viewpoint's distance equal to 1 km. The tilt parameter was reset before each acquisition. The spatial resolution of the images is 25 cm.

Figure 2 | Example of image sample example on the left, used in roof area estimates, and the result of segmentation on the right.

Source: Own elaboration. Collected via Google Earth Pro.

For each municipality studied, image samples of representative urban areas were selected and the roof area was estimated using pixel segmentation, based on the usual orange colouring on the roofs. The representative areas were selected by visual analysis of each municipality, considering the land cover distribution in different sectors. The ratio between the number of pixels of the segmented and the total image was obtained from the proportion of the roof area.

Thus, for each municipality k, a sample of size n was collected and the proportion of the roof area for each one of the n sample images was obtained with the following expression:

$$T_i^k = \frac{N_{seg}^i}{N_{total}^i}, \qquad \text{with } i = 1, 2, \cdots, n \tag{11}$$

where

- T_i^k is the roof proportion in pixels in image i of the municipality k;
- N_{seg}^i is the number of segmented pixels in image i;
- N_{total}^i is the total number of pixels in image i;
- k is the city index, ranging from 1 to 16 in the present study;
- n is the number of different image samples for the municipality k.

The mean of the n proportions was calculated for each municipality k as follows:

$$\overline{T}^k = \frac{1}{n} \sum_{i=1}^{n} T_i^k, \qquad \text{with } k = 1, \cdots, 16 \tag{12}$$

Then, the estimation of roof area for each municipality k was calculated by multiplying the mean proportion of segmented roof pixels and the urban areas obtained from IBGE (2020):

$$AT^k = \overline{T}^k \times A^k_{urb}, \qquad \text{with } k = 1, 2, \cdots, 16 \qquad (13)$$

where

- AT^k is the estimated roof area for municipality k, given in km²;

- A^k_{urb} is the urban area for municipality k, given in km².

2.4 PHOTOVOLTAIC GENERATION AND SUPPLY POTENTIAL

Through the information described in the previous sections, it was possible to estimate the PV generation and energy supply potential of the municipality, which are considered indicators of the capacity for being independent of centralized electricity generation.

Taking into account the 15% efficiency[2] (TOLMASQUIM, 2016, p. 340), the mean monthly solar radiation in 2017 and the roof areas obtained, the estimation of the PV generation potential (F^k_m) for each

municipality k in the month m was obtained through the following expression:

$$F^k_m = I^k_m \times AT^k \times 10^6 \times 0.17 \times H^k_m \qquad \text{with } m = 1, \cdots, 12 \text{ e } k = 1, \cdots, 16 \qquad (14)$$

where

- I^k_m is the mean monthly solar radiation, given in kWh/m² for the municipality k obtained by the mean daily solar radiation per month, given in kWh/m².day, multiplied by the number of days for month m;

- AT^k is the estimated roof area for municipality k, given in km²;

- 106 is the conversion factor from km² to m²;

- 0.15 is the PV energy conversion factor;

- H^k_m is the average direct solar incidence factor in the panels for municipality k in month m, assuming values between 0 and 1.

The mean direct solar incidence factor in the panels (H^k_m) is the mean percentage of the perpendicular incident radiation of the solar flux in the PV module surface, obtained minute by minute from the daily mean of each month, obtained from the relative position of the Sun position vector and the vector normal to the module´s surface.

To assess these vectors, the parameters of the Sun's daily path and module's orientation were adapted to the system of spherical coordinates. In this three-dimensional system, each point and vector are defined through the parameters ρ , θ and φ (STEWART, 2015, p. 927).

The normal to the PV module surface vector $\vec{n}$ was represented with ψ assuming Z_S values, and φ assuming β values, and the Sun's daily path vector $\vec{s}$ was represented with θ assuming Z values, and φ assuming $90-\alpha$ values. Both vectors are unitary since the focus is their direction:

$$\vec{n} = (1,\ Z_S,\ \beta).$$

and

$$\vec{s} = (1,\ Z,\ 90-\alpha).$$

H_m^k for each month was obtained through the vector projection of $\vec{s}$ on $\vec{n}$, which was obtained with the scalar product between $\vec{s}$ and $\vec{n}$ that indicates the projection length (WINTERLE, 2014, p. 61).

The vector $\vec{n}$ was obtained with the surface azimuth angle (Z_S) assuming values in the sequence $\{0,15,\ldots,360\}$ (see section 2.1). Therefore, $\vec{n}$ was obtained in 25 distinct positions, broadly allowing to model orientation.

With a fixed position of $\vec{n}$ for each Z_S value, the vector $\vec{s}$, whose coordinates range with the hour angle (h), dependent on the local standard time (LST), had its positions calculated minute by minute for each average day length in a month with the equations (5), (6), and (7) and then the vector projection modules of $\vec{s}$ on $\vec{n}$ were obtained.

Factor H_m^k was finally obtained by the mean of the vector projection $\vec{s}$ on $\vec{n}$ for each Z_S value along each average day length in a month, with $\vec{s}$ changing minute by minute. The index $m = 1,2,\ldots,n$ indicates the month for which the factor was obtained.

Therefore, H_m^k is given as follows:

$$H_m^k = \frac{1}{25}\sum_{i=1}^{25}\left\{\frac{1}{t}\sum_{j=1}^{t}|\vec{n}_i \cdot \vec{s}_j|\right\}$$

where

- i index is related to the elements of the Z_S values in sequence $\{0,15,\ldots,360\}$;
- j is the month m average day length;
- $|\vec{n}_i \cdot \vec{s}_j|$ is the modulus of the scalar product between $\vec{n}_i$ and $\vec{s}_j$.

When the angle between $\vec{s}$ and $\vec{n}$ was greater than 90°, H_m^k was considered as zero because it means that the direction of $\vec{s}$ is parallel or incident behind the PV module surface.

The monthly and yearly estimations of PV energy supply contribution for each municipality were also obtained. The monthly estimation in percentage (E_m^k) for month m in municipality k was obtained as follows:

$$E_m^k = \frac{100 \times F_m^k}{C_m^k} \qquad (16)$$

where

- F_m^k is the PV generation estimate for municipality k, from equation (14), given in kWh;
- C_m^k is the average monthly energy consumption in sunlight periods for month m in municipality k, given in kWh.

In the present study, energy storage systems were not taken into account, so the PV energy generation potential was measured in sunshine periods. This is reflected by parameter, that is the average consumption in sunlight periods, given by

$$C_m^k = Q_m^k \times K_m^k \qquad (17)$$

where

- K_m^k is the average consumption rate in sunlight periods for municipality k, in month m, given in kWh, between 0 and 1;
- Q_m^k is the mean consumption for municipality k, in month m, given in kWh.

The mean monthly consumption (Q_m^k) was obtained from the annual consumption of each municipality, in São Paulo (2018, p. 23), with the expression below:

$$Q_m^k = \frac{C_{year}^k \times N_m}{365} \qquad (18)$$

where

- N_m is the number of days for month m;
- $N_m/365$ is the month m proportion of the number of days.

The average consumption rate in sunlight periods (K_m^k) was obtained for each municipality, month by month, using the characteristic curve of residential demand available at CPFL (2012, p. 65), which illustrates the energy demand of the 24-h period observed from the Paulista Power and Light Company (CPFL), the supplier of low tension residential consumers in São Paulo state.

The demand rate can be calculated from the demand data, subsequently enabling the calculation of the consumption rate in sunlight periods through the areas under the curve.

Equations (5) and (6) allow obtaining the sunrise and sunset times and sunlight periods, enabling to obtain the area under the demand curve in those periods through numerical integration. Here, the trapezoidal rule was used (ARENALES; DAREZZO, 2017, p. 213).

Thus the sunlight consumption rate (K_m^k) was obtained using the sunlight period area under the demand curve (AS_m^k) and the total area under the demand curve (A_m^k):

$$K_m^k = \frac{AS_m^k}{A_m^k} \quad \text{with} \quad i = 1,2,\ldots,n \quad \text{and} \quad k = 1,2\ldots,16 \,. \quad (19)$$

The estimation of the yearly percentage of PV energy supply for municipality k was obtained as follows:

$$E_{year}^k = \frac{100 \times F_{year}^k}{C_{year}^k} \quad (20)$$

where

- F_{year}^k is the estimation of the yearly PV generation for municipality k, given in kWh;

- C_{year}^k is the average yearly consumption in sunlight periods for municipality k, given in kWh.

Parameter F_{year}^k is given by

$$F_{year}^k = \sum_{m=1}^{12} F_m^k \quad (21)$$

where F_m^k is the PV energy generation potential for municipality k in month m – see equation (14).

The average yearly consumption in sunlight periods (C_{year}^k) for the location of interest is given by

$$C_{year}^k = K_{year}^k \times Q_{year}^k \quad (22)$$

where

- K_{year}^k is the average consumption rate of sunlight periods for municipality k, assuming values between 0 and 1;

- Q_{year}^k is the yearly consumption for municipality k according to São Paulo (2018, p. 23), given in kWh.

For municipality k, the K_{year}^k parameter is the K_m^k yearly mean – see equation (17):

$$K_{year}^k = \frac{1}{12} \sum_{m=1}^{12} K_m^k \quad (23)$$

Therefore, from equations (17) and (22), the consumption in sunlight periods for each municipality was obtained, and, afterwards, the monthly and yearly PV energy supply was estimated using equations (16) and (20) respectively.

2.5 ASSESSMENT OF SUSTAINABILITY AND ENVIRONMENTAL PERFORMANCE

To expand the analysis described so far, it is also necessary to analyze the PV use considering aspects of sustainability and environmental performance, considering sustainability in the environmental, economic and social aspects (GOLDEMBERG, 2015, p. 34).

The energy payback time (EPBT) and the rate of greenhouse gas (GHG) emissions are environmental indicators that allow the assessment of the sustainability and environmental performance of these systems (PENG; LU; YANG, 2013, p. 256).

According to Frischknecht *et al.* (2016, p. 16), the EPBT can be defined as "the period required for a renewable energy system to generate the same amount of energy (in terms of primary energy equivalent) that was used to produce the system itself", while GHG is responsible for maintaining high-temperature levels in the atmosphere – global warming potential – expressed as the equivalent mass of CO_2 (PENG; LU; YANG, 2013, p. 257). EPBT and GHG emissions also take into account the energy consumption and gas emissions of the whole life cycle of the system, from the process of manufacturing to transportation, installation and final use, decommissioning or recycling (PENG; LU; YANG, 2013, p. 256).

Peng, Lu and Yang (2013) offered a rich overview on EPBT and GHG emissions in the assessment of the life cycle of PV systems, where a great data analysis on those parameters is found. Lima, Toledo and Bourikas (2021), Wu *et al.* (2017) and Yue, You and Darling (2014) are among other studies that also offered data in that sense, where in Lima, Toledo and Bourikas (2021) considered PV power plants in Brazil.

Taking into account that most commercial PV modules were based on crystalline silicon cells, among which the monocrystalline silicon cells (mono-Si) have the highest efficiency, this section focuses on data and information on monocrystalline PV (TOLMASQUIM, 2016, p. 336).

The EPBT can be obtained as follows (LIMA; TOLEDO; BOURIKAS, 2021; YUE; YOU; DARLING, 2014):

$$EPBT = \frac{E_{input} + E_{BOS}}{E_{output}/n_G} \qquad (24)$$

where

- E_{input} is the primary energy input during the life cycle, in kWh;

- E_{BOS} is the energy requirement of the balance of system components (support structures, cabling, electronic and electrical components) in kWh;

- E_{output} is the annual electricity generation of the PV system, in kWh;

- n_G is the average conversion rate of primary energy into the electricity grid in the country where the PV system is installed.

The rate of GHG emissions is assessed in different studies that addressed sustainability features of the PV systems, such as in Lima, Toledo and Bourikas (2021), Lukac et al. (2016), Peng, Lu and Yang (2013), and Wild-Scholten (2013) being used as a parameter of sustainability assessment in an environmental sense. In the present study, the rate of GHG emissions was considered as 61 g CO2/kWh for mono-Si PV systems (PENG; LU; YANG, 2013, p. 265). For comparison, the rate of GHG emissions from fossil fuels is estimated at 685 g CO2/kWh (D'ADAMO, 2018, p. 10).

The expected lifetime for PV systems was also assessed in Peng, Lu and Yang (2013), and the mono-Si solar cells have indicated a 30-year lifetime. Additionally, as the present analysis takes into residential account systems, distributed grid-connected, and do not use energy storage, low-capacity inverters presented a 15-year lifetime (PENG; LU; YANG, 2013, p. 263).

On the other hand, regarding the PV energy production system and efficiency estimations for planning purposes, one must consider the most accurate technical information on the module's material must be considered (mono-Si solar cells, for instance) to increase accuracy estimation (NERO et al., 2020, p. 182). In that sense, planning goals are more realistic and achievable.

Regarding the economic aspect, it is essential to consider information on energy generation and energy demand. In an urban environment and considering distributed PV generation, it implies using the available roof area together with solar radiation data (NERO et al., 2020, p. 183; SANTOS et al., 2014, p. 49). Besides, distributed generation tends to decrease financial losses caused by the discontinuity of energy supply related to centralized generation. This type of information and data can lead to a solid background for decision making by the public administrator regarding sustainable urban planning (FONSECA; SCHLUETER, 2015, p. 263; NERO et al., 2020, p. 183).

Regarding the social aspect, the short term effects are also related to GHG emissions, their potential air pollution, and the risk factors associated with human health, as well as their global warming potential (ONAT; BAYAR, 2010, p. 3113).

Another social sustainability feature regards energy supply security and diversity. Here, the intermittency of electric supply represents an important issue in the security context (SANTOYO CASTELAZO; AZAPAGIC, 2014, p. 122), and PV distributed generation might increase this security. Furthermore, PV distributed generation increases the supply diversity in the Brazilian electric matrix, since it mostly consists of hydroelectric generation.

The physical, geographical, and technical PV potential data can also be linked to social sustainability, relating social parameters such as energy demand per capita, population density, population distribution, building characteristics (area, height, and property values), and PV systems already installed (NERO et al., 2020, p. 183).

3 RESULTS AND DISCUSSION

The estimations of PV generation and energy supply were obtained using specific information for each municipality studied. Information is shown in Table 2. Since all municipalities in the study are located left of the Greenwich meridian and in the same timezone, the values of ^{SL} were defined as equal to 45° – see equation (4).

The municipalities studied presented different population classes, based on available data, to increase the scope of analysis.

3.1 SUN'S DAILY PATH

The Sun's daily path was obtained according to the solar altitude angle (α) and the solar azimuth angle (Z), as described in section 2.2. The α parameter changes with a solar declination (δ) and hour angle (h).

The hour angle (h) changes according to the local standard time of the day (LST), which was obtained from sunrise (h_{SR}) and sunset (h_{SS}) times and day length (DL).

Table 2 | Database used for the estimation of PV energy generation and supply.

City	*Id (k)*	*Consumption* (kWh)*	*Urban area (km²)*	*Latitude (º)*	*Longitude (º)*
Águas de São Pedro	1	15,058,321	1.68	-22.6001	-47.8758
Águas de Lindoia	2	46,827,867	3.86	-22.4767	-46.6250
Ourinhos	3	206,322,667	32.21	-22.9831	-49.8788
Bauru	4	921,831,447	75.59	-22.3154	-49.0704
Piracicaba	5	2,012,793,035	94.53	-22.7250	-47.7012
Jundiaí	6	2,000,088,619	101.28	-23.1865	-46.8888
Santos	7	1,391,860,105	34.08	-23.9618	-46.3264
São José do Rio Preto	8	1,157,750,507	108.3	-20.8202	-49.3767
Sorocaba	9	2,037,935,190	122.31	-23.5062	-47.4582
Ribeirão Preto	10	1,856,404,675	134.9	-21.1767	-47.8097
Osasco	11	1,446,265,175	60.42	-23.5317	-46.7973
São José dos Campos	12	1,918,025,049	120.19	-23.1791	-45.8956
Santo André	13	2,791,481,294	63.4	-23.6666	-46.5254
São Bernardo do Campo	14	2,644,526,692	83.58	-23.6944	-46.5616
Campinas	15	3,242,013,676	241.09	-22.9064	-47.0643
Guarulhos	16	3,175,476,963	144.65	-23.4635	-46.5241

*Consumption observed for 2017.

Source: São Paulo (2018, p. 23), IBGE (2020).

Figure 3 shows the average Sun's daily path for each average day length in a month in the municipality of Sorocaba. They have been obtained from the Sun's daily path vector ($\vec{s}$) for each minute of each average day length in a month.

The grey plane is normal to the horizontal plane in the East-West line, and the arrow indicates the true North direction. It is possible to see in January, February, November, and December that the Sun remained most of the day on the southern side of the grey plane, resulting in higher sunlight incidence for south-oriented PV modules in those months.

However, the highest yearly average sunlight incidence occurs for north-oriented modules, as the Sun is most of the time at the northern side of the East-West line. Such details are discussed in section 3.3.

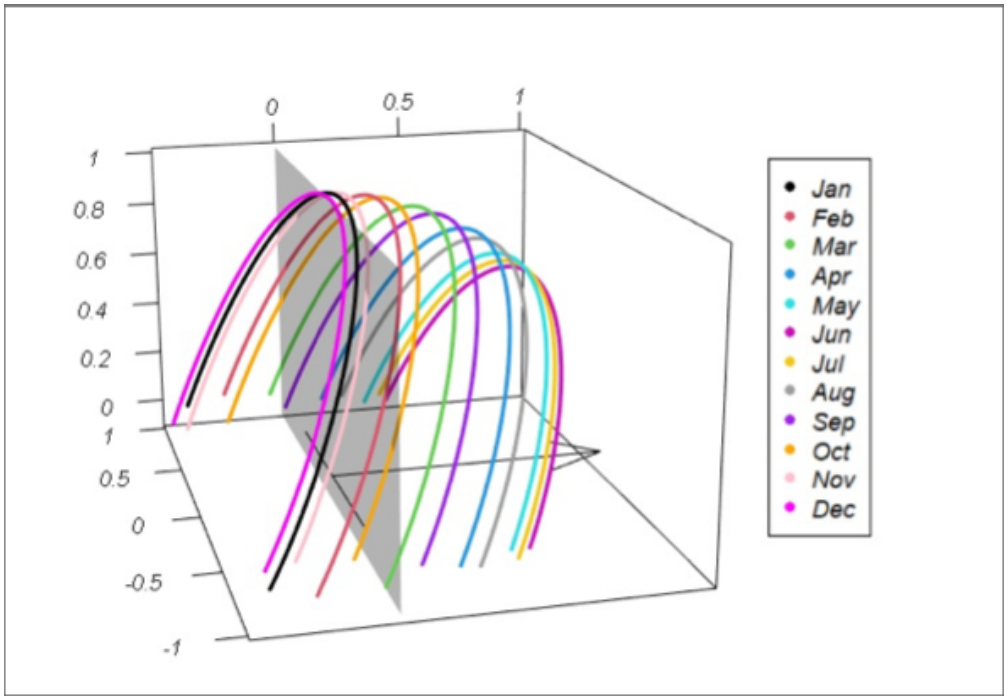

Figure 3 | Sun's daily path in each average day length in a month, for the municipality of Sorocaba.

Source: Own elaboration.

3.2 AVAILABLE AREA

The available area for PV modules was considered the same as the roof areas estimated in the municipalities. Section 2.3 describes the methodology used.

Data of the urbanized area (A_{urb}^{k}) data were obtained from IBGE (2020) and are shown in Table 3, as well as the total area, the estimated roof proportion (AT^{k}) and the estimated roof area (– T_{k}).

3.3 PHOTOVOLTAIC ENERGY GENERATION AND SUPPLY POTENTIAL

The estimation of PV energy generation for each municipality per month was obtained using equation (14) in section 2.4, according to the average monthly solar radiation (I_{m}^{k}), given in kWh/m², and the factor average direct solar incidence on the PV module (H_{m}^{k}). Table 4 shows the obtained values for I_{m}^{k} ,

H_{m}^{k} for each municipality k in the month m was obtained from the mean monthly projections of the Sun path vector ($\vec{s}$) and the normal to the PV module surface vector ($\vec{n}$), minute by minute, for each average day length in a month and changing azimuth surface angle Z_{S} , as described in sections 2.1 and 2.2.

Figure 4 shows the variation of s on n projection mean (vertical axis), in the municipality of Sorocaba (9), according to Z_{S} angle (horizontal axis), for each average day length in a month. Each point represents the mean projection of s on n along each average day length, for every fixed Z_{S} value in $\{0,15,\ldots,360\}$.

Table 3 | Total area, urban area, roof average proportion, and roof estimated area for the municipalities studied.

City	Id (k)	Area (km^2)	Urban area (km^2)	Roof proportion (%)	Roof area(km^2)
Águas de São Pedro	1	3.61	1.68	16.12	0.27
Águas de Lindoia	2	60.13	3.86	16.14	0.62
Ourinhos	3	295.82	32.21	28.50	9.18
Bauru	4	667.68	5.59	31.47	23.79
Piracicaba	5	1378.07	4.53	25.56	24.16
Jundiaí	6	431.21	101.28	18.44	18.67
Santos	7	281.03	34.08	27.87	9.50
São José do Rio Preto	8	431.94	108.30	31.39	34.00
Sorocaba	9	450.38	122.31	27.71	33.90
Ribeirão Preto	10	650.92	134.90	27.90	37.64
Osasco	11	64.95	60.42	33.25	20.09
São José dos Campos	12	1099.41	120.19	37.27	44.80
Santo André	13	175.78	63.40	34.73	22.02
São Bernardo do Campo	14	409.53	83.58	26.33	22.01
Campinas	15	794.57	241.09	24.96	60.17
Guarulhos	16	318.68	144.65	26.09	37.74

Source: Data from IBGE (2019, 2020).

Values of H_m^9 by month have been obtained using the mean vertical axis values of each graph and are shown in Figure 5. Values of H_m^k were obtained similarly from the respective values shown in each graph of Figure 5.

In Figure 4, the relationship between the Sun path, described in Figure 3, and the behaviour of the mean is observed. For January, February and December, the highest values for the projection of $\vec{s}$ on $\vec{n}$ occur when Z_S is close to 180° as the Sun remains most of the time at the southern side of the East-West plane in those months – see Figure 9. It has been defined that $Z_S = 0°$ means that the PV module surface is North oriented, being westwards for the positive direction.

Table 4 | Monthly average solar radiation (I_m^k) obtained values, given in kWh/m².

Id(k)	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
1	150.97	150.08	159.34	157.50	143.22	136.50	143.53	172.67	152.70	161.82	153.00	164.30
2	155.93	153.16	162.75	159.60	150.04	141.00	151.28	172.05	157.80	166.47	156.30	164.92
3	159.03	154.84	166.16	159.30	142.29	133.50	143.22	170.50	150.90	163.37	162.30	174.53
4	159.34	156.52	166.47	160.20	147.25	137.40	148.49	171.74	153.60	168.95	162.90	173.60
5	156.55	154.00	162.75	157.50	145.39	138.00	145.70	170.50	153.90	163.99	157.20	167.40
6	154.07	152.32	160.89	154.50	142.29	135.00	141.98	168.95	151.50	162.75	155.70	168.02
7	138.26	136.92	135.47	129.30	120.28	108.00	110.98	126.17	107.10	113.15	120.60	137.33
8	161.82	156.24	164.30	162.00	154.38	148.80	160.58	183.83	162.00	169.88	162.60	169.88
9	155.62	153.44	158.72	151.20	138.88	131.40	136.71	163.99	148.20	158.10	154.50	168.64
10	159.03	158.48	163.99	161.70	155.00	150.30	160.58	179.18	159.00	167.09	158.40	168.64
11	146.94	147.28	150.66	143.40	132.99	124.80	129.89	157.17	135.90	144.15	142.80	158.41
12	151.59	151.20	153.76	144.90	130.51	124.50	130.82	157.79	139.80	151.28	144.30	160.27
13	141.36	143.92	144.77	136.80	126.48	117.90	123.69	145.70	127.50	134.54	135.90	151.90
14	143.22	144.20	146.63	138.60	128.03	120.00	125.24	148.49	129.90	136.40	138.00	153.45
15	157.17	153.72	162.13	157.50	146.01	138.60	146.94	170.19	154.80	166.16	156.00	168.33
16	147.25	147.56	150.35	142.80	129.89	124.80	129.58	155.93	135.00	143.22	139.50	155.93

Source: Data from Crecesb (2020).

The H_m^k behaviours for all municipalities are illustrated in Figure 6, where the vertical axis indicates H_m^k values and are limited between 0.4 and 0.65. The horizontal axis indicates the months. Few changes in the behaviour of this parameter were observed from one municipality to the other.

Each point in the graphs in Figure 5 indicate the mean projection of $\vec{s}$ on $\vec{n}$, for all Z_S values in each average day length in a month. For instance, in the case of Sorocaba, each point in its graph in Figure 5 is the mean of the observed values of the graph of the respective month in Figure 4.

In Figure 6, the highest potential was observed for the municipality of Campinas, followed by São José dos Campos. These municipalities presented the highest estimations of roof area, as shown in Table 5, which shows the municipalities ordered decreasingly by values of estimated roof area.

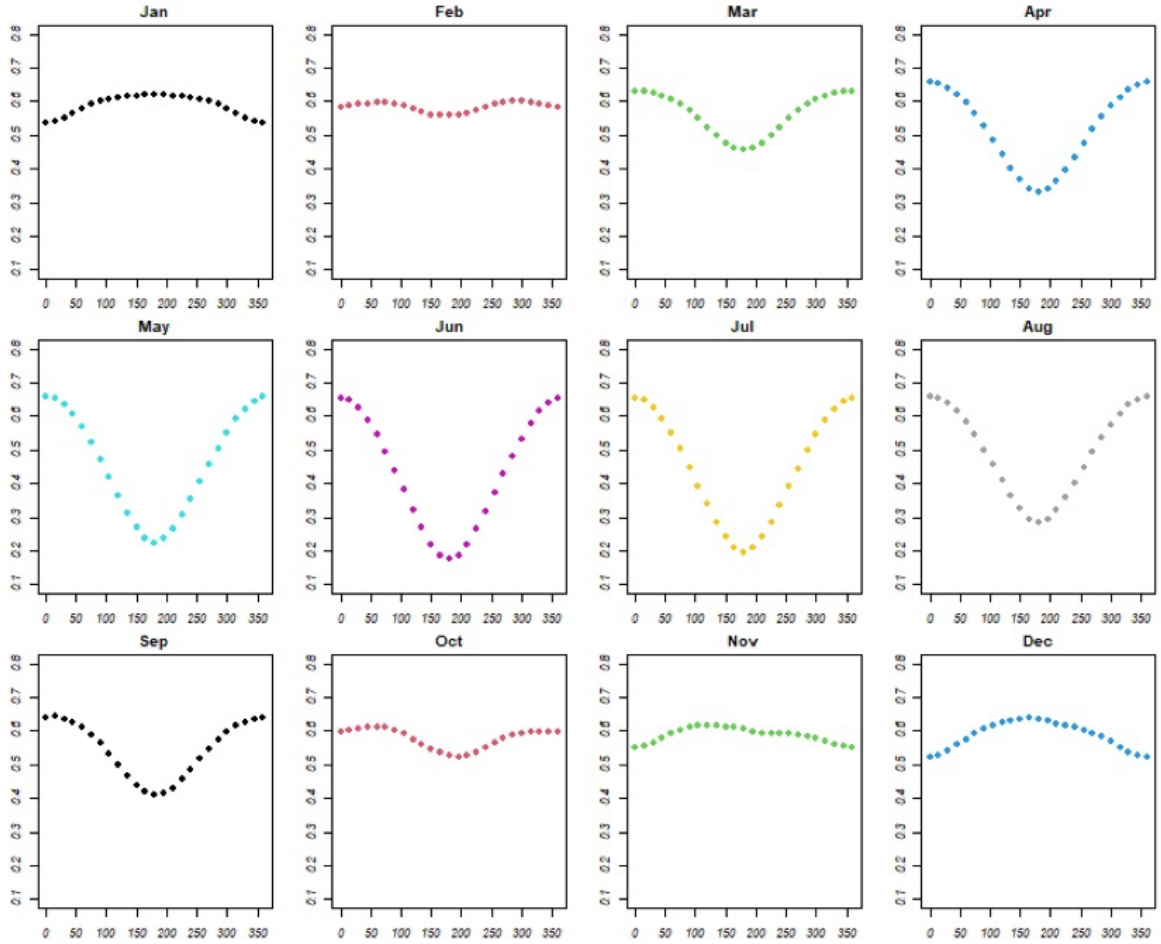

Figure 4 | Projection for the monthly means of →S on →n (vertical axis), according to Z_s (horizontal axis) for the municipality of Sorocaba.

Source: Own elaboration.

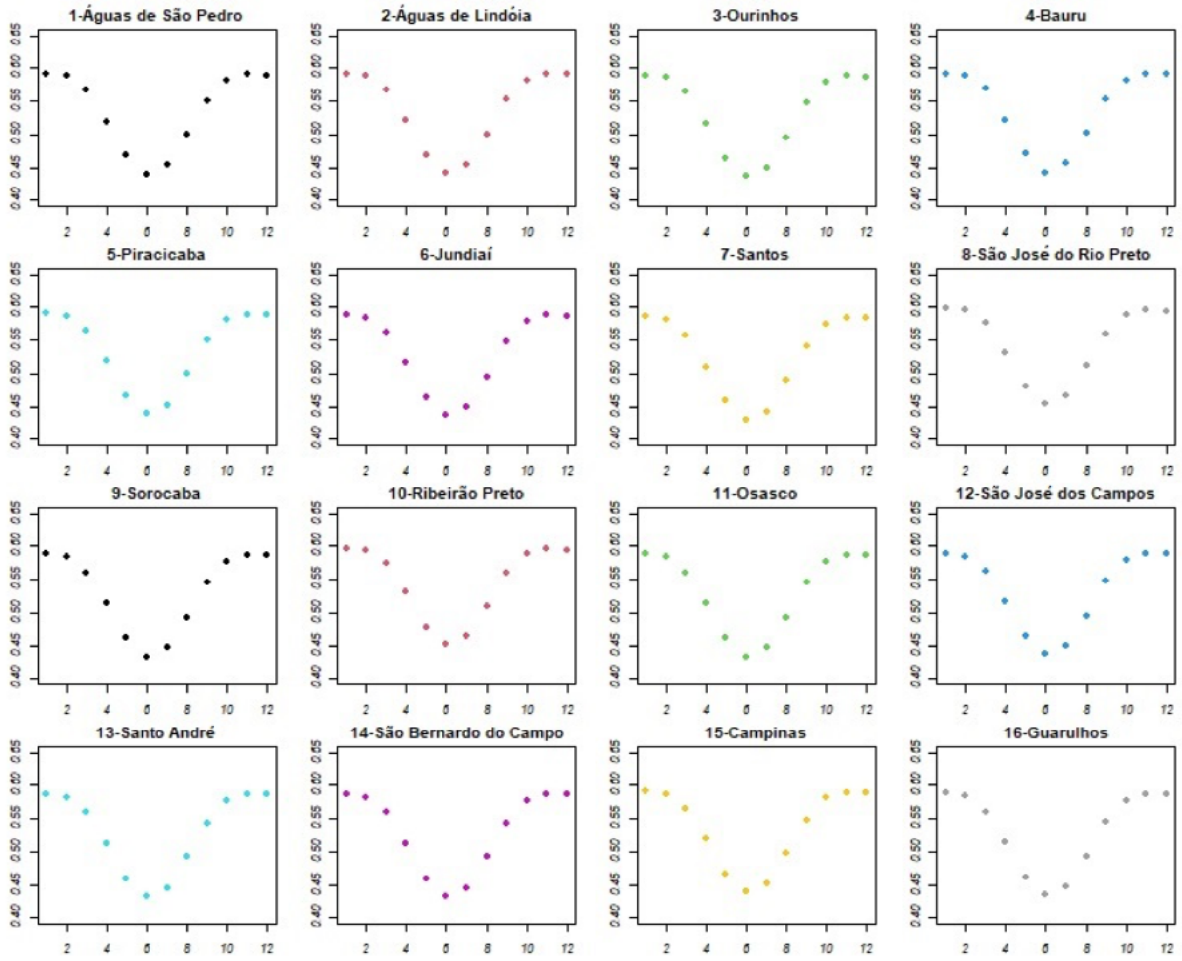

Figure 5 | H_m^k values (vertical axis) by month (horizontal axis), for each municipality.

Source: Own elaboration.

It was also noticed that higher roof areas did not necessarily mean higher generation potential in situations where two municipalities have similar roof areas, such as in Guarulhos and Ribeirão Preto. In this case, Ribeirão Preto has a higher generation potential. Mean monthly solar radiation (I_m^k) and the factor average direct solar incidence in the panels (H_m^k) have a more significant influence on the PV energy generation potential.

Thus, it is possible to verify that, for the municipalities studied, the generation potential is directly related to the roof area. Looking at I_m^k and H_m^k parameters, which range according to the city location, it can be seen that the small variations observed from one municipality to the other do not significantly affect the PV generation potential.

In addition, for municipalities with similar roof areas, I_m^k and H_m^k have greater influence in the PV energy generation potential, as observed in the numbers obtained for São José do Rio Preto and Sorocaba.

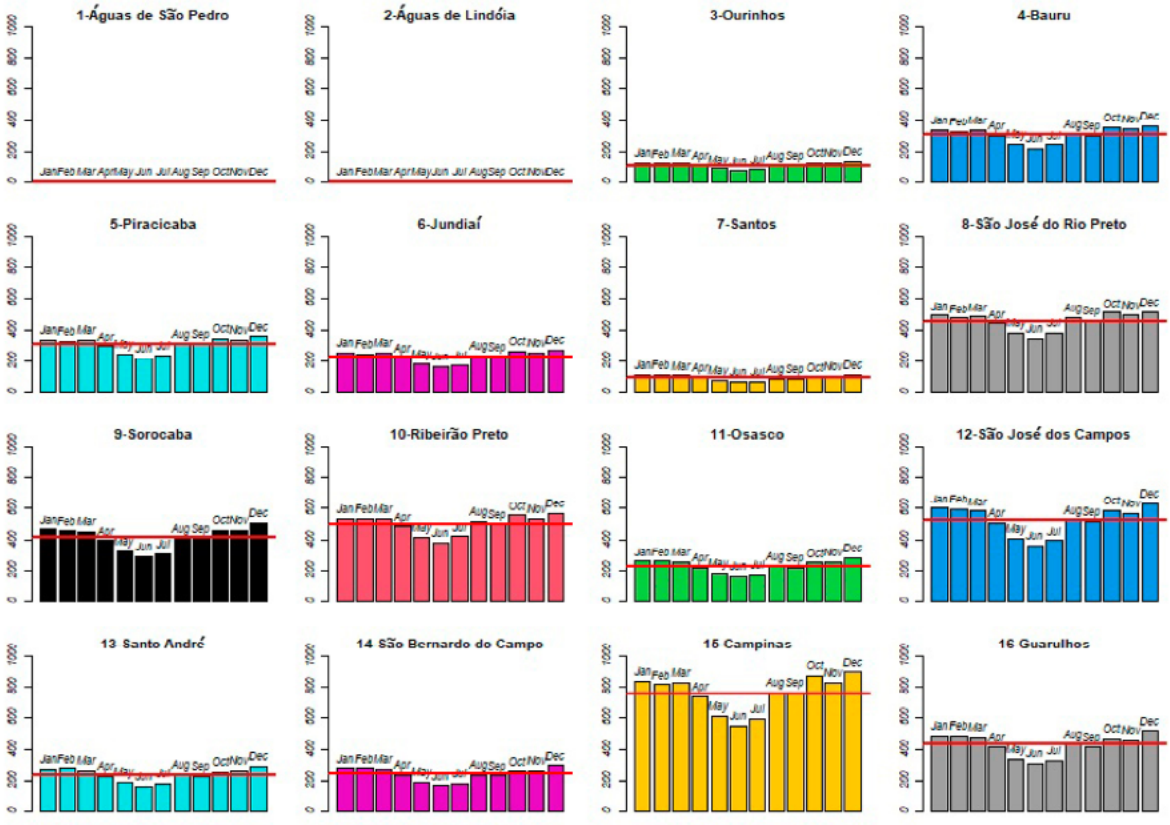

Figure 6 | Monthly PV energy generation potential, given in GWh.

Source: Own elaboration.

After estimating the PV energy generation, monthly and annual energy supply potentials were calculated using equations (16) and (20).

Since the methods for energy storage were not considered, the supply potentials were obtained according to the consumption in the sunlight periods, using equations (17) and (22).

Monthly PV energy supply depends on the average monthly consumption in sunlight periods (C_m^k), according to equation (16).

The monthly PV energy supply (E_m^k) was obtained using the PV energy generation potential (F_m^k) and the average consumption in sunlight periods (C_m^k) for each municipality, using equation (16). The results are shown in Figure 7.

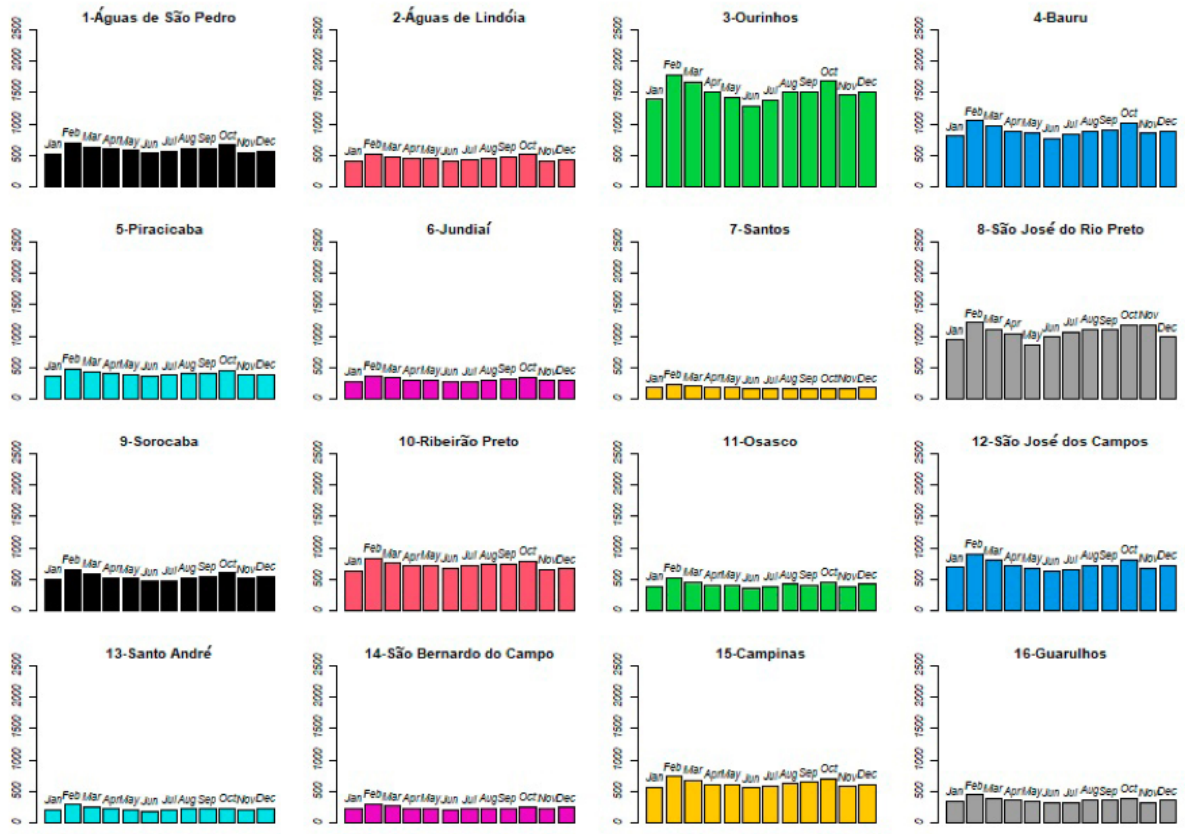

Figure 7 | Potential monthly PV energy supply, in percentage (%).

Source: Own elaboration.

The results show that all the municipalities studied, E_m^k was greater than 100%. It means that the consumption in sunlight periods could have been supplied by PV energy for the municipalities studied, as long as the entire roof area was covered with PV modules.

As aforementioned, E_m^k depends on the PV energy generation potential (F_m^k) and the average consumption in sunlight periods (C_m^k). Thus, municipalities with low generation potential may have high supply potential due to low consumption in sunlight periods, as occurs in Ourinhos. Likewise, municipalities with high generation potential, such as Campinas, may have lower supply potential due to higher consumption in sunlight periods.

Some analyzes were carried out to clarify the possible influence of some variables over energy consumption. The first analysis addressed the relationship between energy consumption and the population of a given municipality.

A scatter plot with energy consumption and the population is shown in Figure 8(a) and highlights a trend of linear growth in energy consumption linear with population. The linear fit line is also shown in the figure. The 0.912 linear correlation factor was obtained between energy consumption and population, showing a substantially positive linear behaviour.

The relationship between energy consumption and roof area also was analyzed, since both affect the PV energy supply. Figure 8(b) illustrates the respective scatter plot.

The linear correlation factor between energy consumption and roof area (0.731) indicates a positive linear relationship, although not so strong as the previous one, indicating that an increase in energy consumption might not represent an increase in the roof area in the same proportion.

Table 5 shows the roof area, energy consumption, and population data, decreasingly ordered according to the roof area. From this data, it is possible to observe that the parameters of consumption and population do not change in the same way as the roof area parameters. This context allows understanding the 1,500 % PV supply of Ourinhos even with relatively low generation potential, as well as the numbers obtained for the municipality of Campinas, which shows high generation potential but an average supply potential due to high energy consumption.

As mentioned in section 2.4, the yearly supply potential was also obtained using equation (20). This parameter depends on the yearly PV energy generation potential (F^{k}_{year}) and on the yearly mean consumption in sunlight periods (C^{k}_{year}) – see equations (21) and (22). The values obtained for these parameters are shown in Table 6, decreasingly ordered according to the generation potential.

It is also possible to notice from Table 6 that the generation potential does not behave like energy consumption due to the aspects previously discussed, highlighting that high energy generation potential does not necessarily mean high energy supply potential.

The yearly energy supply potential was estimated from data in Table 6, shown in Figure 9.

3.4 ASSESSMENT OF SUSTAINABILITY AND ENVIRONMENTAL PERFORMANCE

As mentioned in section 2.5, the EPBT and the rate of GHG emissions, together with the life cycle analysis, are parameters that allow assessing the sustainability and environmental performance of PV systems.

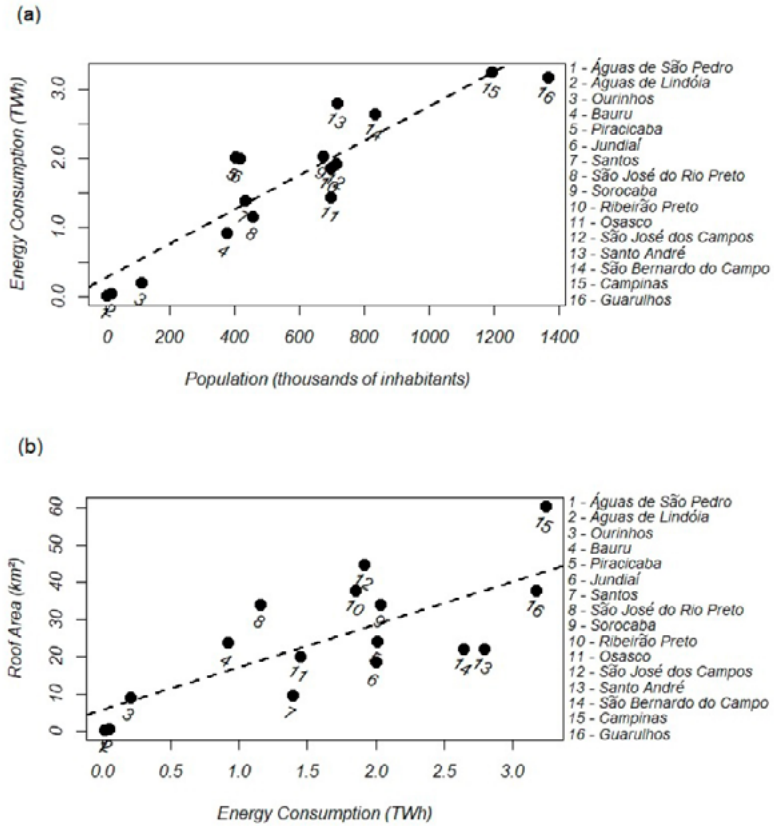

Figure 8 | Scatter plots with energy consumption and population (a) and energy consumption and roof area (b), with linear fit lines.

Source: Own elaboration.

According to data available in Peng, Lu and Yang (2013) and Wu *et al.* (2017), mono-Si PV modules E_{BOS} were defined for each municipality studied with the energy demand of BOS components multiplied by each respective estimation of roof area given in Table 3. Then, with equation (24), the EPBT for each city has been estimated.

City	Id (k)	Roof area (km^2)	Energy consumption (kWh)	Population
Campinas	15	60.165	3,242,013,676	1,194,094
São José dos Campos	12	44.798	1,918,025,049	713,943
Guarulhos	16	37.739	3,175,476,963	1,365,899
Ribeirão Preto	10	37.642	1,856,404,675	694,534
São José do Rio Preto	8	33.997	1,157,750,507	456,245
Sorocaba	9	33.896	2,037,935,190	671,186
Piracicaba	5	24.159	2,012,793,035	400,949
Bauru	4	23.789	921,831,447	374,272
Santo André	13	22.016	2,791,481,294	716,109
São Bernardo do Campo	14	22.008	2,644,526,692	833,240
Osasco	11	20.092	1,446,265,175	696,850
Jundiaí	6	18.672	2,000,088,619	414,810
Santos	7	9.498	1,391,860,105	432,957
Ourinhos	3	9.18	206,322,667	112,711
Águas de Lindóia	2	0.623	46,827,867	18,599
Águas de São Pedro	1	0.271	15,058,321	3,380

Table 5 | Roof area, energy consumption, and population ordered decreasingly ordered according to roof area.

Source: Data from IBGE (2020), São Paulo (2018, p. 23) and IBGE (2019).

The total energy demand of BOS components obtained was 19.44 kWh/m^2 for support and cabling (PENG; LU; YANG, 2013, p. 263) and 25.87 kWh/m^2 for the inverter (WU *et al.*, 2017, p. 72), while n_G was considered to be 0.625 (LIMA; TOLEDO; BOURIKAS, 2021, p. 9).

E_{input} was considered as 794.44 kWh/m² by Peng, Lu and Yang (2013), also multiplied by each respective estimation of roof area. E_{output} was the yearly PV energy generation estimated for each municipality – see Table 6. The EPBT estimated for the municipalities studied are shown in Table 7.

The rate of GHG emissions was obtained for each municipality considering 61 g CO_2/kWh (PENG; LU; YANG, 2013, p. 265), and are shown in Table 7. The values represent the CO2 amount that would have been emitted during all life cycles of the PV systems considered.

The value for each municipality in Table 7 represents approximately 9.5% of all the GHG emissions that would have occurred in one year if the same amount of PV energy had been generated using fossil fuels, considering the emission rate of 685 g CO_2/kWh.

Table 6 | Yearly PV generation potential and consumption in sunlight periods, decreasingly ordered according to generation potential.

City	Id (k)	Generation potential (kWh)	Sunlight periods consumption (kWh)
Campinas	15	9,098,009,791	1,446,649,860
São José dos Campos	12	6,276,436,007	855,860,260
Ribeirão Preto	10	5,978,571,442	828,364,045
São José do Rio Preto	8	5,458,623,695	515,433,914
Guarulhos	16	5,145,630,348	1,416,959,878
Sorocaba	9	4,941,689,180	909,366,508
Bauru	4	3,676,466,762	411,339,207
Piracicaba	5	3,650,558,284	898,147,587
São Bernardo do Campo	14	2,906,391,824	1,180,039,491
Santo André	13	2,870,918,144	1,245,613,506
Jundiaí	6	2,771,744,658	892,478,629
Osasco	11	2,757,781,453	645,351,785
Ourinhos	3	1,389,140,726	92,065,206
Santos	7	1,123,188,583	621,075,179
Águas de Lindóia	2	95,231,800	20,895,509
Águas de São Pedro	1	40,339,574	6,719,317

Source: Data from São Paulo (2018, p. 23).

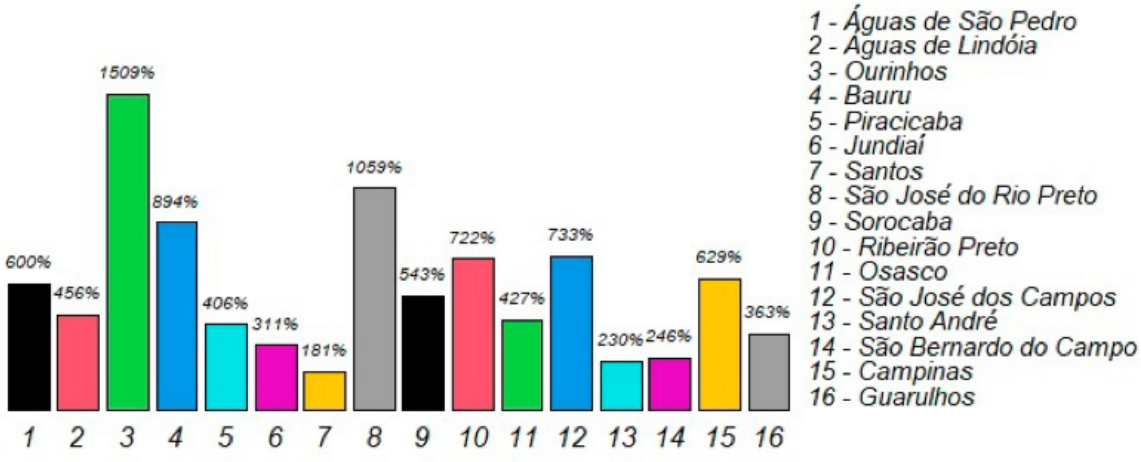

Figure 9 | Yearly energy supply potential, in percentage (%).

Source: Own elaboration.

It is also worth mentioning that, according to Peng, Lu and Yang (2013), the highest EPBT observed for mono-Si PV systems was 2.7 years, while its expected lifetime period was of 30 years. In Lima, Toledo and Bourikas (2021, p. 12), who considered Brazilian PV power plants, the highest EPBT observed was 4.69 years.

Table 7 | EPBT estimated for the municipalities studied, in years, and GHG emissions estimated for the municipalities studied, in tons of CO_2.

City	*EPBT (years)*	*GHG (tons of CO_2)*
Águas de São Pedro	3.1	2,622.07
Águas de Lindóia	3.0	6,190.01
Ourinhos	3.1	90,294.15
Bauru	3.0	238,970.34
Piracicaba	3.1	237,286.29
Jundiaí	3.1	180,163.40
Santos	3.9	73,007.26
São José do Rio Preto	2.9	354,810.54
Sorocaba	3.2	321,209.80
Ribeirão Preto	2.9	388,607.14
Osasco	3.4	179,255.79
São José dos Campos	3.3	407,968.34
Santo André	3.6	186,609.68
São Bernardo do Campo	3.5	188,915.47
Campinas	3.1	591,370.63
Guarulhos	3.4	334,465.97

Source: Own elaboration.

4 CONCLUSIONS

According to this study, the municipalities with the highest PV energy supply potential were Ourinhos, São José do Rio Preto, and Bauru, which have shown favourable rates of consumption and generation potential. As discussed in the previous section, these results depend mainly on the energy consumption and roof area of the municipalities. On the other hand, the municipalities with the highest PV generation potential are Campinas, Guarulhos, São Bernardo do Campo, and Santo André. However, due to high rates of consumption in the sunlight period, they presented lower energy supply potential. It must be emphasized that the energy supply potential was higher than 100% for every municipality studied, indicating that all the energy consumption could have been supplied by PV generation. São José do Rio Preto showed the lowest yearly energy supply potential, 180.85%.

The results show that all the municipalities studied have the potential to reduce their dependence on centralized generation, at least during sunlight periods. To include the night periods in the analysis, some complementary forms of electric generation or energy storage may have to be considered.

Finally, the highest EPBT obtained was 8.6 years (Santos), which is far lower than the expected lifetime of 30 years of PV systems. This indicates that those systems would return the energy consumed during their life cycle in a relatively short period if compared with their expected lifetime. Besides, the estimates indicate that the PV systems would have generated approximately 9.5% of the GHG emissions if fossil fuels had been used to generate the same amount of energy. Regarding social and economic sustainability, distributed PV generation represents supply security and the improvement of diversification, decreasing the dependence of municipalities on centralized generation, allowing broader access to energy, and reducing discontinuity and maintenance costs.

These results also bring a reflection to promote scientific arguments and subsidies capable of enhancing PV generation in Brazil, both from the point of view of natural potential and technical feasibility, since they have been obtained considering distributed generation from existing household structures. In addition, there are some possible directions for future works, like the analysis of the economic viability of installation costs and payback time.

NOTES

1. According to Aneel, Tonne of Oil Equivalent (toe) is a unit of energy, which one unity represents the amount of energy released by burning one tonne of crude oil.

2. The conversion efficiency was defined as equal to 15% as most commercial PV modules nowadays use silicon (Mono-Si) as their main component, and that is their lowest estimated efficiency (TOLMASQUIM, 2016, p. 340).

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Food and sustainability at university restaurants: analysis of water footprint and consumer opinion

Alimentação e sustentabilidade em restaurantes universitários: análise de pegada hídrica e da opinião dos consumidores

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doi:10.18472/SustDeb.v12n2.2021.37939

Received: 13/05/2021
Accepted: 21/06/2021

ARTICLE – VARIA

ABSTRACT

Objective: Analyze comparatively the sustainability of menus developed by two university restaurants (UR) in the State of Paraná using the water footprint (WF) and the opinion of diners as parameters. Methods: WF was calculated based on 46 menus in each unit and data on diners through questionnaires for 750 people analyzed with Mann Whitney and Pearson's chi-square. Results: The highest WF averages were from omnivorous menus compared to vegetarians and UR2 had averages higher than UR1. As for the opinion of diners about UR1, there is greater satisfaction with prices, vegetarian options, and greater knowledge about organic and purchases of family farming (FF) products. Conclusions: Therefore, RU1 is closer to the assumptions of a sustainable diet than UR2, but both should review their menus concerning WF and carry out work with diners on food and sustainability.

Keywords: Water footprint. Sustainability. Institutional Nutrition. Sustainable Diets. Food Policy.

RESUMO

Objetivo: Analisar comparativamente a sustentabilidade dos cardápios ofertados por dois restaurantes universitários (RU) do estado do Paraná a partir da pegada hídrica (PH) e da opinião dos comensais. Método: A PH foi calculada com base em 46 cardápios em cada unidade, e os dados sobre os comensais foram obtidos com aplicação de questionários para 750 pessoas e realizadas análises de Mann Whitney e qui quadrado de Pearson. Resultados: As maiores médias de PH foram dos cardápios onívoros, se comparados aos vegetarianos, com o RU2 apresentando médias superiores ao RU1. Quanto à opinião dos consumidores sobre o RU1, há maior satisfação com os preços, com as opções vegetarianas e maior conhecimento sobre as compras de orgânicos e de agricultores familiares. Conclusões: O RU1 se mostra mais próximo aos pressupostos de uma dieta sustentável que o RU2, mas ambos devem rever seus cardápios em relação à PH e realizar trabalhos com os comensais sobre alimentação e sustentabilidade.

Palavras-chave: Pegada hídrica. Sustentabilidade. Alimentação Coletiva. Dietas Sustentáveis. Políticas Alimentares.

1 INTRODUCTION

One of the challenges of the 21st century is to make food production viable while using fewer natural resources. It has already been pointed out that the food systems need to be repositioned so that they can supply not only food on a large scale but also quality diets (MASON; LANG, 2017).

Corroborating the discussions that intertwine food and environmental and health issues, the proposal for sustainable diets emerges. These discussions point out that the current agri-food system has consequences that can be identified in the global context in terms of nutritional and health, economic and environmental issues. According to FAO, sustainable diets are those with low environmental impact, which contribute to food and nutritional security and healthy life for future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair, nutritionally adequate, safe and healthy while optimizing natural and human resources (FAO, 2014).

Pragmatically, the criteria for measuring what a sustainable diet is are quite broad, complex and still under construction, for they require analyses of aspects related to its nutritional, environmental, social, cultural, and economic adequacy (MARTINELLI; CAVALI, 2019; MASON; LANG, 2017).

In Brazil, few academic studies have analyzed sustainable diets, although they are on the rise in European countries especially (TRICHES, 2021). There are even fewer studies using environmental criteria for this analysis, such as water, carbon, ecological and nitrogen footprints, among other parameters (GARZILLO, 2018; STRASBURG; JAHNO, 2015). Also, few studies have attempted to understand the role of the consumer or the user of collective food services to identify their perceptions and knowledge about the topic.

Hence, this study aimed to address one of the most widely used environmental footprints, namely, water footprint x(WF), to identify the impact of food on the environment and to seek to understand the role of consumers by understanding their satisfaction, their impressions, and their knowledge about the food provided by the URs of two Federal Universities in the State of Paraná, Brazil. Thus, the analysis intended here is to use water footprint as an environmental parameter and some socio-cultural and economic parameters, indicated by consumers' impressions, to compare and find which of the two sites has indicators closer to a sustainable diet.

The water footprint is an indicator of water use. It has been more widely addressed in scientific discussions after 2002 when Arjen Hoekstra (HOEKSTRA, 2002) pointed out the use of water in large production chains. Its distinctive feature is to consider the indirect use of water, for the WF of a product/food is the total volume of water used to produce it throughout the entire production chain. The relevance of this indicator lies in the

identification of the immense amount of the planet's freshwater used for livestock and agriculture. Most of its use is for irrigation of cereals crops (BRANDÃO, 2020; TOM; FISCHBECK; HENDRICKSON, 2016).

On the other hand, considering the sustainability of food in the socio-cultural context, among other aspects, also means taking into account the opinion of consumers. For today's society, eating is not only a biological need but also a decisional process based on economic, political and cultural aspects. It is acknowledged that the consumer can act upon the process and foster a new agri-food model (PORTILHO, 2015; TRICHES, 2020; TRICHES; SCHNEIDER, 2015). Making more room for the precepts of sustainable diets requires rethinking both the reduction of the demand for certain raw materials and energy, as well as new consumption patterns, values, and levels (MASON; LANG, 2017; TRICHES, 2020).

Finally, this study uses University Restaurants from Public Universities as sites for the survey to include the role of the State and its public food programs in the promotion of sustainable food systems.

2 METHODS

This is a quantitative and cross-sectional study carried out at two university restaurants. It was based on official documents from the Federal Institutions of Higher Education (Ifes) regarding the UR's menus for one semester (one academic term) and the Term of Reference of the contract notice.

Regarding the choice of the cases studied, we sought to investigate two federal universities in Paraná. In the state, four Federal Universities (Ifes) operate Federal University of Paraná (UFPR), consisting of ten campuses; Federal University of Technology – Paraná (UTFPR), consisting of 13 campuses; Federal University of the Southern Frontier (UFFS), with two campuses in Paraná; and the Federal University of Latin American Integration (Unila), with one *campus*. Among the three remaining options, two were chosen by meeting the following criteria: a) location – Ifes geographically close to each other; and b) similar physical structure of UR, considering the total number of meals served (lunch and dinner).

Using these criteria, the UFFS's *Laranjeiras do Sul campus*, identified as "RU1" (RU stands for 'University Restaurant' in Portuguese), and the UTFPR's *Pato Branco campus*, identified as "RU2", were chosen. The UTFPR's *Pato Branco campus* is in the Southwest Region of the State of Paraná, 137 kilometres from the UFFS's *Laranjeiras do Sul campus*, which is in the Center-South region of the State of Paraná. The two Ifes are managed through an outsourcing system with a concession agreement free of charge.

The diners' data were collected through the application of structured questionnaires with questions about satisfaction (about the price paid, menus, respect for eating habits, meat protein portion, vegetarian portions) impressions (about healthy and sustainable menus) and knowledge about the provenance of the products (about organic food and FF products purchases). Convenience sampling was used, and the survey was carried out during the lunch period of a day identified as the busiest day of the week according to the UR's managers. Thus, there were 300 diners at RU1 and 450 at RU2.

For the Water Footprint assessment, data were collected from the menus (23 omnivorous and 23 vegetarian menus) of the first semester of 2019 of each UR, public notices for services, and restaurant production records. The water footprint of each meal was obtained through the amount of raw food *per capita* of each UR. The average amount *per capita* of each food item was obtained from the kitchen prep sheets and control records of the total amounts of each dish prepared, provided by the key personnel of the URs and divide by the number of diners at each site (300 RU1 and 400 RU2).

For RU2, which operates differently regarding the provision of the main protein dish (meats), the average amount *per capita* of the two options provided was obtained. On this site, diners can take both the dishes offered. The first meat protein option, which is required by the public notice, is portioned according to an established amount in grams. However, not all diners take this option, for there are

those who prefer the second one, as well as those who take both. Therefore, we considered the average amount *per capita* of both options because they are made of different types of meat, such as chicken and beef, which have different water footprints.

The next step in the WF assessment was the tabulation of data, considering the multiplication of the amount *per capita* of each food item by its WF (litres of water per kilo of food). The WF values were obtained from the list of products' WF estimates by Mekonnen and Hoekstra (2011).

Descriptive analyses were performed to find the mean and standard deviation of the WFs for the URs and the proportions in the questionnaires applied to diners. The non-parametric Mann-Whitney test was used to verify differences between the WFs of the UR and the types of menus on these sites, i.e. omnivore and vegetarian. To verify the differences between proportions, Pearson's Chi-square test was used. These analyses were performed using the free software PSPP, and statistical significance was considered when $p < 0.05$.

This research was submitted and approved (number 62708716.3.0000.5564) by the Ethics Committee of the Federal University of the Southern Frontier (UFFS).

3 RESULTS

Regarding the WF assessment, the means of omnivore menus are significantly higher than the vegetarian menu. However, even though the mean WF of RU1 is lower than that of RU2, there were no considerable differences between the two, except for their omnivore menus (Table 1).

Table 1 | Average WF of the URs and their respective menus – The state of Paraná, 2019.

Variable	*N*	*Mean*	*Standard deviation*	*M-W Test*
RU1	46	1641.53	954.44	0.24
RU2	46	1946.99	1173.43	
Omnivore menus	46	2523.61	1072.62	0.000
Vegetarian menus	46	1064.92	312.30	
Omnivore menus of RU1	23	2179.68	1043.71	0.005
Omnivore menus of RU2	23	2867.53	1008.30	
Vegetarian menus of RU1	23	1103.38	410.41	0.41
Vegetarian menus of RU2	23	1026.45	167.26	

Source: Prepared by the authors (2019).

In the assessment of the daily WF of each site (Table 2), it was found that in the omnivore profile, whenever there is red meat, the WF is higher. On the other hand, in the vegetarian profile, the highest WFs are related to the days when the menu establishes the association of two types of legumes. In both sites, the lowest WFs refer to the days when dishes are based on textured soy protein and roasted vegetables.

For RU2 there is a wider range of comparisons since two meat protein options are analyzed in the same menu. The average portion of animal protein offered in RU1 was 164g, while that in RU2 was 223g. Besides the RU2's menu has 50% more frequency of red meat than the RU1's. In both sites, the lowest WFs refer to the days when dishes are based on chicken, pork, or fish.

Table 2 | Daily water footprint of URs' menus from January to July 2019 – Paraná

	Vegetarian menu		*Omnivore menu*			
Day	R.U1	R.U2	R.U1	Protein option	R.U2	Protein option
1	943	1,286	1,760	Pork	4,389	Beef*
2	1,031	1,041	1,416	Chicken	1,799	Chicken and egg
3	2,507	885	4,701	Beef	3,421	Beef and Chicken
4	951	894	1,422	Chicken	3,119	Beef and Chicken
5	766	965	1,418	Chicken	1,667	Chicken and Pork
6	812	1,292	3,106	Beef	4,395	Beef*
7	1,402	1,041	1,564	Fish	1,799	Chicken and Egg
8	1,479	890	1,711	Pork	3,582	Beef and Pork
9	1,069	876	3,365	Beef	3,101	Beef and Chicken
10	1,654	926	2,235	Chicken	1,628	Chicken and Pork
11	827	1,286	1,390	Pork	4,389	Beef*
12	881	1,041	1,394	Chicken	1,799	Egg and Chicken
13	1,273	885	1,513	Chicken	3,577	Beef and Pork
14	867	876	3,688	Beef	1,794	Pork and Chicken
15	1,630	862	3,886	Beef	1,565	Chicken and Pork
16	857	1,286	1,467	Chicken	3,267	Beef and Chicken
17	905	1,041	3,348	Beef	3,583	Beef and Chicken
18	1,251	885	1,413	Fish	3,421	Beef and Chicken
19	856	951	1,523	Chicken	1,477	Chicken and Pork
20	876	1,386	3,396	Beef	3,328	Beef and Chicken
21	960	881	1,671	Pork	1,926	Chicken and Pork
22	801	1,038	1,338	Chicken	3,385	Beef and Fish
23	767	1,086	1,395	Chicken	3,530	Beef and Chicken
Mean	1,103	1,026	2,179		2,867	

*Two options of beef dishes;
Source: Prepared by the authors (2019).

The results of diners' satisfaction and perceptions of the dishes/menus offered are shown in Table 3.

Table 3 | Opinion of diners about the foods/menus offered by two URs in the State of Paraná – 2019.

Variable	*RU1*		*RU2*		*p*
	N	%	N	%	
Satisfaction with the price paid					
Very dissatisfied	9	3.0	15	3.3	
Dissatisfied	30	10.0	52	11.6	0.000
Satisfied	63	21.0	324	72.0	
Very satisfied	198	66.0	59	13.1	

Variable	RU1		RU2		p
	N	%	N	%	
Satisfaction with the menu					
Very dissatisfied	40	13.3	80	17.8	
Dissatisfied	40	13.3	57	12.7	0.43
Satisfied	210	70.0	297	66.0	
Very satisfied	10	3.3	16	3.6	
Satisfaction with respect for eating habits					
Very dissatisfied	6	2.0	50	11.1	0.000
Dissatisfied	41	13.7	32	7.1	
Satisfied	208	69.3	328	72.9	
Very satisfied	45	15.0	40	8.9	
Satisfaction with the meat protein portion					
Satisfied	183	61.0	255	56.7	
Dissatisfied – it should be larger	105	35.0	174	38.7	0.49
Dissatisfied – it should be smaller	0	0.0	0	0.0	
Does not eat meat	12	4.0	21	4.7	
Satisfaction with vegetarian options					
Satisfied	111	37.0	95	21.1	0.000
Dissatisfied – should be more varied	33	11.0	62	13.8	
Dissatisfied – there are not any	0	0.0	1	0.2	
Does not care	156	52.0	292	64.9	
The UR purchases FF products					
Yes	45	15.0	18	4.0	0.000
No	27	9.0	9	2.0	
Does not know	228	76.0	423	94.0	
The UR purchases organic products					
Yes	48	16.0	28	28.0	0.000
No	24	8.0	9	2.0	
Does not know	228	76.0	413	91.8	
The menus are healthy					
Yes	240	80.0	333	74.0	0.065
No	21	7.0	54	12.0	
Does not know	39	13.0	63	14.0	
The menus are sustainable					
Yes	138	46.0	156	34.7	0.000
No	53	17.7	48	10.7	
Does not know	109	36.3	246	54.7	

Source: Prepared by the authors (2019).

We observed that there are differences between the URs in terms of satisfaction with the price paid, eating habits, and the offer of vegetarian options, as RU1 shows higher satisfaction than RU2 regarding these aspects. It is worth noting that RU1 has a greater diversity of ovolactovegetarian dishes (15). On this site, the highest percentage of vegetarian dishes is of textured soy protein (35%), followed by vegetable-based dishes (26%) and egg-based dishes (13%). At RU2, however, only four variations of dishes were identified. The most commonly used ingredient was textured soy protein, 46%, followed by egg-based dishes, with 29%. These data might help explain the higher satisfaction of the RU1 diners with the vegetarian dishes.

4 DISCUSSION

When assessing the WF values of foods, it was found that vegetables have lower WF when compared to animal-based products. In this study, WF in the two sites was found to be proportionally lower whenever animal-based foods were reduced, especially red meat.

The data in this study corroborate the literature, demonstrating that lower environmental impacts are found in the plant-based food profile (HATJIATHANASSIADOU, 2019) and that omnivore menus' mean FW is up to 60% higher than vegetarian menus' mean (STRASBURG; JAHNO, 2015). This is easy to explain by considering that in the red meat production process it takes an average of three years to slaughter an animal and produce 200 kg of meat (net weight). It is stipulated that throughout its life, this animal consumed 1,300 kg of feed, 7,200 kg of forage, 24 m^3 of water for drinking and 7 m^3 of water for hygiene/slaughter procedures. Therefore, at the end of this process, 1 kg of beef has 15,500 litres of water embedded in its production. When comparing the WFs of 1 kg of beef and 1 kg of lettuce, beef's WF is 65 times higher than the vegetable's WF (TOM; FISCHBECK; HENDRICKSON, 2016).

It is also worth noting that with the types of meat offered in the omnivorous protein dish, beef was more relevant when compared to other used meats (pork, chicken and fish). According to Gerbens-Leenes, Mekonnen, and Hoekstra (2013), in general, beef has a larger total WF than pork, which in turn has a larger WF than poultry. As for the WF of fish, a study shows that this depends a lot on the type of fish and whether they are produced in farmed fish or at sea, with the second form having much smaller impacts (YUAN *et al*, 2017).

When comparing the WF of both URs, it was found that there was a difference in WF between the omnivore menus. This can be explained by RU2's strategy to offer two meat protein options with the main goal of reducing costs. However, this has a negative influence on the sustainability of the menu, with a higher WF than the RU1's respective menu.

In addition, even a greater frequency of red meat on the menu does not guarantee a higher level of satisfaction of RU2's diners regarding the price paid for the meal and the level of satisfaction with eating habits when compared to RU1. The price charged has a significant role in the users' perception, and satisfaction with this aspect allows an estimate of the access to food as an indicator of compliance with public policies and programs focused on this theme (IZEL; GASPAR; COSTA, 2016).

Dietary patterns centred on the consumption of animal-based products are correlated with higher levels of environmental impacts. Thus, food sustainability is found to be closely related to society's consumption profile (CARMO, 2017). For their part, consumers are placed as "choosers", with strong power to spread changes within market models. The opinion of consumers regarding sustainable consumption, specifically regarding meat, points out that the level of environmental awareness of individuals is a determinant that directly influences their food profile (BARONE; NOGUEIRA; GUIMARÃES, 2018; UNITED NATIONS SYSTEM STANDING COMMITTEE ON NUTRITION, 2017).

For both sites, data reveal a significant percentage of those who express the desire for a larger portion of meat (about one-third of the diners). It is known that the consumption of meat *per capita* at the national level is above the recommended amount (CARVALHO, 2018; CARVALHO *et al*., 2016). and that this reflects the Brazilian food culture. It should be noted that the meat group is displayed noticeably on the menus because it is considered the "main dish". This practice should be reviewed and discussed because, although it considers the cultural dimension of sustainable diets, it clashes with their environmental dimension. Therefore, a balance point must be reached so that eating habits can be respected without causing environmental damage.

Another noteworthy finding when analyzing the opinion of diners is their lack of concern regarding the presence of vegetarian dishes on the menu. Studies show that the intention to reduce meat consumption as a justification for environmental sustainability is still low among consumers (BARONE; NOGUEIRA; GUIMARÃES, 2018; CARVALHO, 2018). On the national scene, some initiatives to address the issue within the URs can be identified, such as the *Segunda Sem Carne* ("Meat-free Monday") campaign, which proposes the removal or reduction of meat consumption at least one day a week, presumably on Monday (UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL, 2019).

A lower percentage of vegetarian consumers and/or adherents of the meatless profile indicate satisfaction with the variety of dishes. A higher level of satisfied diners at RU1 compared to RU2 may be related to menu planning. At RU1 menu planning is monthly, thus it has a higher level of flexibility for the inclusion of items according to the seasonality, while RU2's planning has less flexibility. It appears that the lower variety of dishes at RU2 resulted in a higher percentage of diners pointing out the need to improve it compared to RU1.

However, it is important to consider that most vegetarian dishes are soy-based and that there are controversial issues in this regard not only because of the number of pesticides used in such crop but also because it is predominantly transgenic (MESSINA; BURKE, 2017). In addition, consumption of this commodity reflects the homogenization of food, loss of food diversity, environmental pollution, and social exclusion (AZEVEDO, 2011). Even a decade and a half after the beginning of the planting of transgenic soy in Brazil, there are different positions on the existence of risks to human health. It is imperative to consider that there is a strong game of power and political and economic interests that prevail in debates advocating its cultivation, as well as obscurantism regarding these reflections. However, it is undeniable that transgenics are not included in any production paradigm considered ecologically or socially sustainable (CORTESE *et al*., 2018).

The transition to a more sustainable food profile is a complex process, strongly rooted in social, cultural and economic aspects. However, reducing the consumption of animal-based products is a crucial aspect to achieve healthier and more sustainable diets, and the improvement of this situation, among other factors, is linked to the consumption profile that society establishes (CERUTTI, 2017).

Thus, this study reveals that this population's awareness and knowledge about food sustainability is at an early stage since most of them are unaware of the origin of the food they consume (whether it comes from family farming - FF - or not), as well as its characteristics (organic or not), and whether the menus offered are sustainable. In the context of RU1, the lower percentages of unawareness may be related to the fact that the University itself has environment and food and nutritional security as a premise. And, more specifically, the UFFS's *Laranjeiras do Sul campus* has a Postgraduate Program in Agroecology and Sustainable Rural Development, and the theme emerges in discussions about the UR's operation.

Thus, it is necessary to consider that the act of placing the power in consumers' hands may reflect the increase of their authority, the reappropriation of knowledge and skills that can be implemented in their daily life practices (PORTILHO, 2015), leading to their claiming for more sustainable dietary patterns.

However, moving this discussion only to the field of consumption would be like transferring responsibility and regulatory action to the private sphere and seeking solutions to collective problems at the individual

level. Therefore, advancements are desired, and to go through this path it is important not only to ensure there are spaces to discuss the theme and encourage consumers' reflections but also to debate the issue with larger spheres, both public and private (CERUTTI, 2017; OLIVEIRA; JAIME, 2016).

5 FINAL CONSIDERATIONS

At the general level, there is no difference in water footprint between the menus of the two URs investigated. However, when comparing their omnivore menus, a difference in WF was evidenced. The strategy adopted by RU2 to reduce costs harms the sustainability of the menu, which has a higher WF.

Differences in water footprint were also evidenced between omnivore and vegetarian menus, which corroborates the literature and suggests revisions in the quantity and frequency of meat available in the menus, especially red meat. Therefore, one of the indications of this study is that the professionals responsible for preparing the menus of university restaurants offer more meat such as chicken and fish, reducing red meat. In addition to the review of omnivorous menus, more vegetarian options besides soy protein should be considered, seeking to meet nutritional needs, but also the diversification of menus with the addition of other vegetable sources such as unconventional food plants, for example. Therefore, enabling the cooks for these new preparations is necessary.

On the other hand, it is necessary to work with consumers so that they also seek to change their eating practices towards health and sustainability. This survey sought to understand a little more the opinions of diners on these aspects. Again, differences were found between the restaurants. In RU1 the consumers reveal greater satisfaction with the price paid and with vegetarian options as well as greater awareness of purchases of FF products and organic products. Their responses were also more affirmative regarding the sustainability of the menus offered in the UR. However, in both units, a small number of vegetarian diners was identified, while a large share of respondents, conversely, would like to have a bigger meat protein portion.

Based on these findings, we conclude that RU1 was more compliant than RU2 with the criteria used here for a sustainable diet assessment. However, it does not mean that RU1 can be regarded as a role model. Both sites proved to need adjustments in their collective catering to reduce WF and encourage actions that elicit diners' behaviours, like food education campaigns, towards sustainability.

Public food programs must be conducive to good environmental practices. In this sense, this study assumes that the State can be an essential actor in changing eating practices when it seeks to offer meals that have a smaller environmental impact, in addition to being nutritious. Considering that the public served is university students, these changes can be leveraged, aligning this offer to the environmental and nutritional discussions that the academic context can provide. Therefore, these places can be used for the transition to more sustainable diets and the mitigation of climate change and the rational use of natural resources.

Finally, one of the limitations of this study is the use of international WF references. This can be considered a limitation because it does not necessarily reflect the reality of the water use of food produced in the country. However, so far there are not many studies that have used methodologies such as life cycle analysis to determine the WF of Brazilian foods which need to be changed with more research on this.

It seems likely that, as the sites investigated, other URs in Brazil may have similar indicators. However, it is necessary to carry out more studies to investigate different aspects of food sustainability, especially in places funded by public entities, to reallocate resources to make not only healthy but also sustainable food available to the population.

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Scenarios for oil palm expansion in degraded and deforested lands in the Brazilian Amazon to meet biodiesel demand

Cenários para expansão de palma de óleo em áreas degradadas e desflorestadas na Amazônia brasileira para demanda de biodiesel

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doi:10.18472/SustDeb.v12n2.2021.35201

Received: 15/11/2020
Accepted: 10/05/2021

ARTICLE – VARIA

ABSTRACT

Palm oil production for biodiesel in Brazil is characterized by its high productivity in some environmental conditions, under the Sustainable Palm Oil Production Program. The program seeks to avoid deforestation for oil palm cultivation, recover degraded lands, and focus on social inclusion and family farming. This paper assesses the possible socio-environmental impacts of the expansion of palm oil until 2030, focusing on land-use change and impacts. Land-use data came from the TerraClass initiative for the analysis of degraded forests using geoprocessing. We produced two oil expansion scenarios. The first one reflects current trends in palm oil production expansion and deforestation in Pará State (S1). The second one considers the exclusive use of deforested/degraded land for oil palm crops (S2). The results demonstrate that degraded/deforested land in the current palm oil-producing municipalities is only sufficient for the projected level of expansion for 2020, requiring a stronger public policy to recover degraded areas for oil palm cultivation with social inclusion of family farming.

Keywords: Palm oil. Degraded land. Biofuels. Amazon region.

RESUMO

A produção de óleo de palma para biodiesel no Brasil é caracterizada por sua alta produtividade em algumas condições ambientais no âmbito do Programa de Óleo de Palma Sustentável. Esse programa visa evitar o desmatamento para o cultivo do dendê, recuperar áreas degradadas e ter como foco a inclusão social e a agricultura familiar. Este artigo objetiva uma avaliação dos impactos socioambientais da expansão do óleo de palma até 2030, com foco nas mudanças e impactos no uso da terra. Os dados de uso da terra foram obtidos pelo TerraClass para análise de desmatamento e áreas degradadas usando análise de geoprocessamento. Produzimos dois cenários para a expansão do óleo de palma, refletindo as tendências atuais de expansão da produção de dendê no estado do Pará (S1) e o desmatamento considerando apenas o uso de terras desmatadas/degradadas para o cultivo de palma (S2). Os resultados demonstram que as áreas degradadas/desmatadas localizadas nos atuais municípios produtores de dendê são suficientes apenas para o nível de expansão projetado para 2020, exigindo políticas públicas mais fortes de recuperação de áreas degradadas para o cultivo de dendê com inclusão social da agricultura familiar.

Palavras-chave: Óleo de palma. Áreas degradadas. Biocombustíveis. Região Amazônica.

1 INTRODUCTION

Biofuels can be a suitable option for replacing fossil fuels since their use promotes sustainable development and mitigates climate change, but benefits and/or contributions to sustainability and climate change mitigation depend on biofuel production practices, because the associated greenhouse gas (GHG) emissions could be equivalent to, or even greater than the corresponding fossil fuel emissions, especially when the land-use policies in place and the management of biofuel production are not efficient (FARGIONE *et al*., 2008; LAPOLA *et al*., 2010; SCHARLEMANN; LAURANCE, 2008; SILALERTRUKSA; GHEEWALA, 2012; WICKE *et al*., 2008; YUI; YEH, 2013). First-generation biofuels can be a threat to ecosystems when uncontrolled expansion occurs (IEA, 2013).

Oil Palm (*Elaeis guineenses Jacq.*) is one of the most productive oilseeds in the world, yielding 368 tonnes/km^2/year (VILLELA, 2009, 2014), whilst soy, for example, only produces 42 tonnes/km^2/year (BRITO, 2007). Palm oil is largely produced in Malaysia and Indonesia, and these countries are responsible for approximately 90% of worldwide palm oil production. However, as mentioned, the environmental impacts of inappropriate land-use management and intensive deforestation can result in a substantial level of GHG emissions. In addition, the consequent displacement of small farmers and local communities has been significant (CARTE *et al*., 2019; LORIS, 2017). Hence, internationally, social and environmental Non-Governmental Organizations (NGOs) have criticized palm oil expansion because of these negative impacts (BROWN; JACOBSON, 2005; STATTMAN; MOL, 2014), prompting the creation of the RSPO (Roundtable on Sustainable Palm Oil), an international multi-stakeholder organization created in 2006. The RSPO develops criteria for palm oil production considering sustainability in addition to the production and economic use of palm oil (RSPO, 2007). About 20% of palm oil production in the world was certified by the RSPO in 2017 (CARLSON *et al*., 2017). Compared to these major palm oil-producing countries, the level of production in Brazil is still incipient, only 0.5% of global production.

In 2003, the Brazilian government launched the National Program for the Production and Use of Biodiesel (PNPB) to increase energy security through the sustainable production of biodiesel from oilseeds. This program has focused on social inclusion and regional development, with an emphasis on job and income generation and the sustainable use of various oilseeds. The implementation of this program should also have led to a reduction in GHG emissions. Financial incentives have been provided to foster the production of various crops. A mandatory mix of 2% of biodiesel (B2) from oilseeds and/or animal fats into fossil fuel-based diesel was initially required in 2008. This amount was then raised gradually to 5% (B5) in 2010, completed 10% in 2018 and there are plans to increase the percentage to 20% by 2030 (B20) (BRAZIL, 2012). At the start of the PNPB program, most of the sources for biodiesel

consisted of soybean and animal fats. This indicates that despite the increase in oilseed production, the multi-use potentials of various crops have not yet been fully explored (SILVEIRA, 2013). Brazil cultivates a large diversity of feedstocks, such as castor bean, oil palm, soybean (*Glycine max L.*), jatropha, and sunflower in the most favourable regions of the country (the northeast, north, central-west, south and southeast regions, respectively) according to the PNPB. Furthermore, the environment of the Amazon region is suitable for the cultivation of oil palm and is considered to provide an opportunity to increase biodiesel crop production to meet domestic and international demands (SILVEIRA, 2013).

Because of its high productivity and high adaptability to the edaphoclimatic conditions in northern Brazil, the oil palm plantations have expanded in Pará State from 2010 (522 km^2) (with the start of the Sustainable Palm Oil Production Program) to 2019 (1,644 km^2), an increase of 32% in oil palm plantations for cropping (125 km^2/year in the period 2010-2019), based on data from IBGE/Sidra (2021). Considering the accuracy of official data sources to be limited, Brandão and Schoneveld (2015) used remote sensing techniques and estimated there were 2,556 km^2 of oil palm plantations in Pará in 2014. In general, estimates from other data sources have varied from 2,069/km^2 (BRANDÃO; SCHONEVELD, 2015) to 3,300 km^2 (GLASS, 2013).

Pará is the focus of oil palm expansion because of the suitability of the climate and the agricultural conditions, besides land availability (BENEZOLI *et al*., 2021; VILLELA, 2014). From 2016 to 2019, production in Pará accounted for more than 90% of Brazilian palm oil production (FURLAN JÚNIOR, 2006; IBGE/SIDRA, 2021).

Considering Brazil's background in biofuel production and use, as well as the increased domestic demand for palm oil (OLIVEIRA *et al*., 2013), the Brazilian government has been struggling to launch and enforce guidelines for sustainable palm expansion through the establishment of environmental programs such as the Agroecological Zoning (ZAE) regulations (EMBRAPA, 2010) and the Sustainable Palm Oil Production Program (BRASIL, 2010), both launched in 2010. According to those guidelines, only lands mapped as deforested or degraded (after 2008) should be used for oil palm expansion, aiming to avoid massive deforestation and its related impacts. The ZAE indicates that 297,000 km^2 of deforested and degraded land is available for cultivation of oil palm crops (approximately 5% of the Amazon Region), and 128,000 km^2 of these lands are available in Pará (EMBRAPA, 2010; VILLELA, 2014), implying a high availability of land and potential for palm oil production. For comparison purposes, the total area of Brazil is 8,520,000 km^2 and that of Pará state is 1,240,000 km^2 (the second-largest state in Brazil).

The use of degraded lands for the cultivation of bioenergy crops reduces the production of negative environmental and social impacts because these lands are unsuitable and economically unattractive for agricultural production (HUNSBERGER *et al*., 2014; LIMA *et al*., 2011; RFA, 2008; SCHUBERT *et al*., 2009; STATTMAN; MOL, 2014). The expansion of palm oil production into deforested lands can bring environmental and socio-economic benefits, such as a reduction in the importation of diesel, the creation of jobs and income, the promotion of social inclusion and regional development, and a positive role for degraded land and abandoned areas (ALMEIDA *et al*., 2020; BRANDÃO, 2019; COSTA, 2004; GLASS, 2013; LEES *et al*., 2015; STATTMAN; MOL, 2014), albeit oil palm plantations have poor habitat value for birds and only support modest carbon stocks in the Amazon region (ALMEIDA *et al*., 2020; LEES *et al*., 2015).

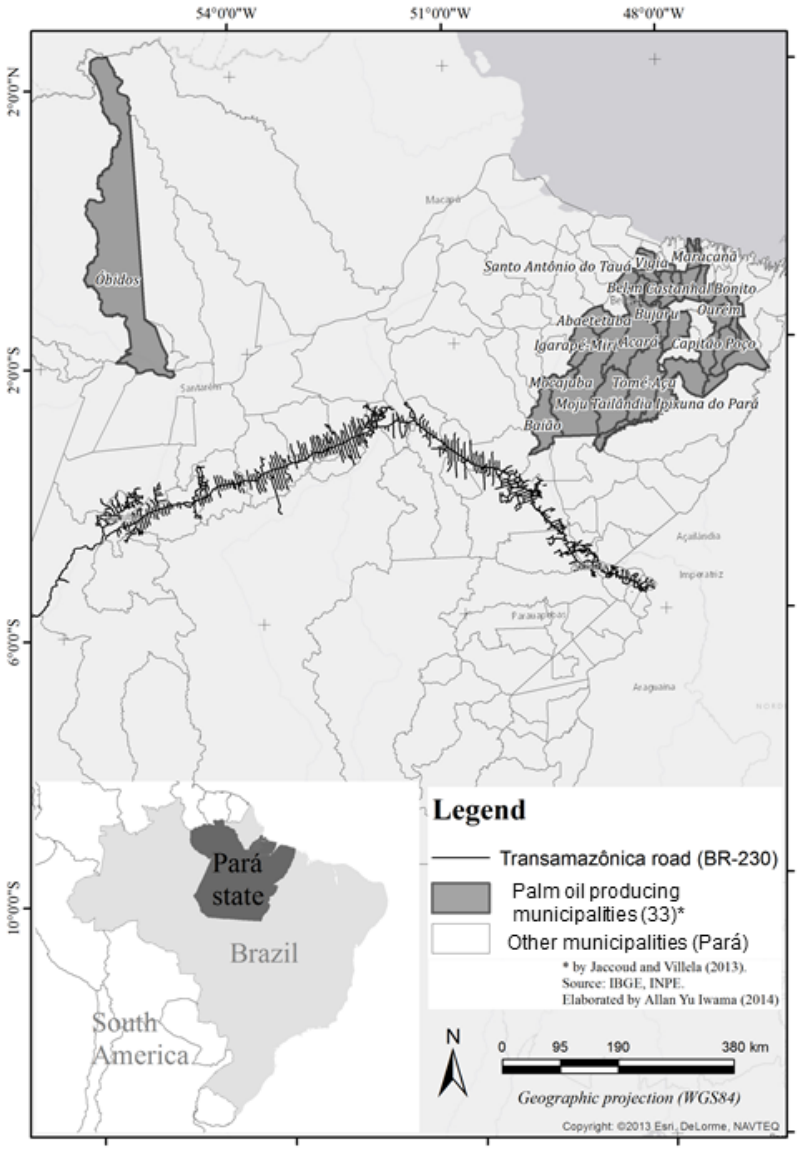
Given that context, the purpose of this paper is to develop and analyse two scenarios for palm oil expansion, focusing on the dynamics of the resultant land-use changes and their related GHG emissions, based on degraded forest and degraded land. Data provided by the TerraClass initiative (TERRACLASS, 2012), produced by remote sensing and GIS tools to identify potentially suitable land (KOH *et al*, 2011; RFA, 2008), can provide a strong background for evaluating available land for oil palm crops, considering current sustainability guidelines for the palm oil program in Brazil. Therefore, for each scenario, changes in land availability and distribution were analysed, aiming to assess multiple options to better support future decision-making in this field.

2 MATERIAL AND METHODS

2.1 STUDY AREA

The Brazilian state of Pará is a focus for palm oil expansion because of the suitable environmental, social and economic conditions, especially in the palm oil-producing municipalities. Therefore, for this research, Pará and its producing municipalities were chosen as the study area. The state is in the eastern portion of the Amazon region, is Brazil's second-largest state and has 144 municipalities. The main economic activities are mining, logging, agriculture and cattle raising (BOLETIM REGIONAL DO BANCO CENTRAL DO BRASIL, 2013). The climate is tropical, with a mean annual temperature of 26°C and consistent rains throughout the year (see IBGE <http://www.ibge.gov.br/estadosat/>). The producing municipalities are in the north-eastern portion of the state, surrounding the capital city, Belém. Their main economic activity is agriculture (Figure 1), associated with the losses in ecosystem services in the last two decades because of the significant cropland changes (LI *et al*., 2019). Figure 1 shows the study area which has been increasing during recent years (BRANDÃO; SCHONEVELD, 2015; EMBRAPA, 2010; FURLAN JÚNIOR, 2006; VILLELA, 2014).

Figure 1 | Study area – main palm oil producing municipalities in Pará state-Brazil



Source: Adapted from data by BRANDÃO; SCHONEFELD, (2015); JACCOUD; VILLELA, 2013.

Table 1 | Main palm oil producing municipalities in Pará state-Brazil

Municipality	*Abandoned pasture (ha)*	*Territory (ha)*	*% Aband. pasture*
Santa Luzia do Pará	18,320,1	132,487,3	13.8
Capitão Poço	26,518,5	281,720,2	9.4
Ourém	5,096,0	62,942,1	8.1
Garrafão do Norte	14,624,6	185,278,7	7.9
Ipixuna do Pará	24,646,9	539,715,3	4.6
Tomé-Açu	23,907,4	529,574,1	4.5
Baião	13,058,6	325,628,1	4.0
Bonito	2,235,6	58,766,0	3.8
Igarapé-Açu	3,110,3	83,157,5	3.7
Moju	32,427,4	996,099,9	3.3
Tailândia	13,979,1	456,799,0	3.1
Concórdia do Pará	1,754,2	73,631,6	2.4
São Domingos do Capim	3,991,6	174,170,9	2.3
Castanhal	2,426,2	107,239,0	2.3
São Francisco do Pará	1,051,1	49,803,2	2.1
Inhangapi	889,0	49,910,1	1.8
Santo Antônio do Tauá	916,4	56,402,2	1.6
Santa Maria do Pará	755,8	47,940,3	1.6
Terra Alta	330,9	21,651,8	1.5
Nova Esperança do Piriá	4,545,7	297,768,9	1.5
Santa Isabel do Pará	1,024,1	74,821,9	1.4
Bujaru	1,339,1	103,630,0	1.3
Nova Timboteua	575,1	51,672,0	1.1
Santa Bárbara do Pará	301,0	29,112,7	1.0
Acará	4,412,1	449,812,2	1.0
Abaetetuba	1,501,0	166,823,3	0.9
Mocajuba	754,4	88,373,1	0.9
Óbidos	22,595,1	2,841,885,6	0.8
Vigia	397,3	58,950,6	0.7
Igarapé-Miri	647,2	206,653,8	0.3
Benevides	29,4	18,428,9	0.2
Maracanã	66,6	81,075,5	0.1
Belém	43,7	111,910,2	0.0

Source: Adapted from data by BRANDÃO; SCHONEFELD, (2015); JACCOUD; VILLELA, 2013.

2.2 METHODOLOGY

To develop scenarios for oil palm expansion in degraded and deforested lands, the first step was to define these lands. For this paper, we assumed that degraded land that is suitable for oil palm cultivation is the land cleared of natural vegetation and is currently characterised by a low level of biodiversity (CÂMARA; VALERIANO; SOARES, 2006; FAO, 2013; GINGOLD *et al*., 2012); more specifically, land that the TerraClass initiative, based on data of the PRODES mapping of deforested areas in the Amazon, classified as 'abandoned pasture'. In other contexts, the concept 'degraded land' may be based on different criteria such as 'forest carbon', as in the case of oil palm expansion in Indonesia (GINGOLD *et al*., 2012).

The methodology was organized into 3 steps: **Step 1** – geodatabase to produce overlay maps; **Step 2** – calculations of land conversion and carbon release; and **Step 3** – carbon release scenarios – Figure 2.

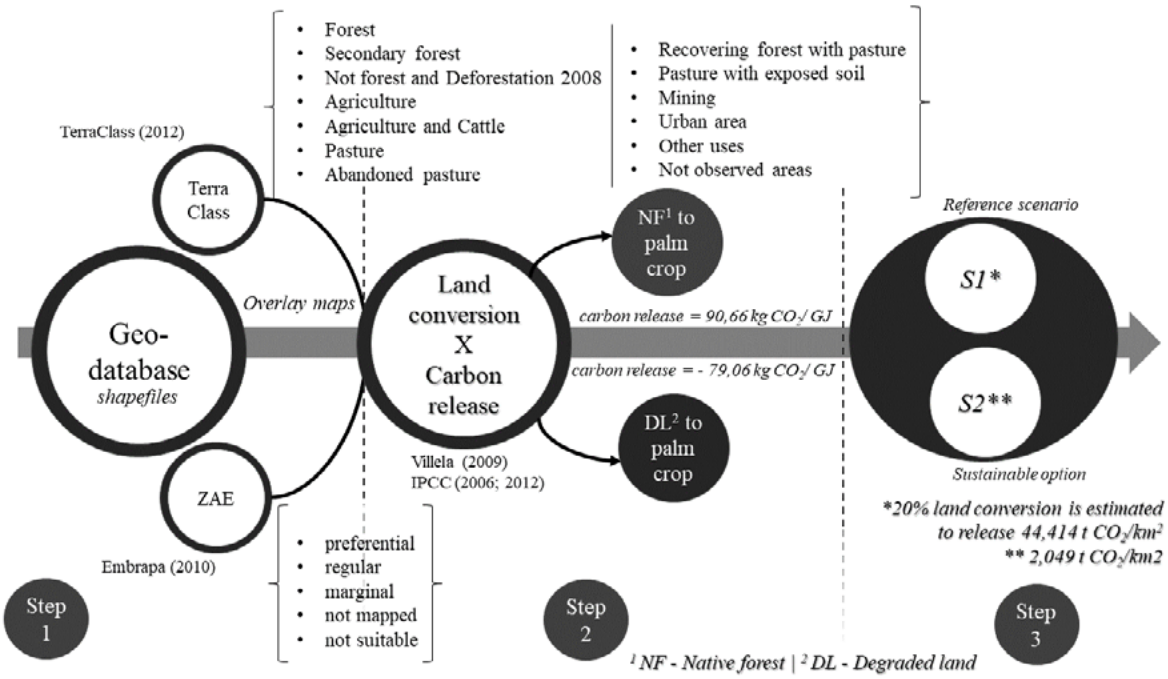


Figure 2 | Methodology following 3 steps for carbon release scenarios
Source: Prepared by authors.

Step 1. Data on deforested and degraded lands were collected from the TerraClass initiative (TERRACLASS, 2012). The TerraClass was developed by the Amazonia Regional Center (CRA) in partnership with the Brazilian Agricultural Research Corporation (Embrapa), which is responsible for qualifying deforestation in the Amazon as defined in Brazilian Law (Legal Amazon) and this provides important subsidies for a better understanding of land-use and land cover in the region. The land classification categories developed by TerraClass are: *Forest, Secondary forest, Not forest and Deforestation 2008, Agriculture, Agriculture and Cattle, Pasture, Abandoned pasture, Recovering forest with pasture, Pasture with exposed soil, Mining, Urban area, Other uses,* and *Non observed areas*. Abandoned pasture, which is deforested and/or degraded land according to the Sustainable Palm Oil Production Program, is the land class designated for oil palm expansion.

Step 2. Carvalho *et al*. (2015), with the support of geoprocessing techniques, analysed land-use availability to assess the real extent of land suitable for oil palm expansion available both in the current palm oil-producing municipalities and in Pará state as a whole. Their analysis served as support for scenario development. The land-use data were depicted in the form of polygons and were overlaid with the boundary of Pará state obtained from IBGE, enabling the spatial analysis of land-use.

Step 3. Two scenarios were developed based on these calculations. The oil palm plantation area reached 1,644 km^2 in 2019 (SIDRA/IBGE, 2021). Brandão and Schoneveld (2015) questioned the accuracy of data sourced from IBGE, considering its limited human and financial capacity and suggest the land demand of oil palm crops in 2014 was 2,556 km^2 (BRANDÃO; SCHONEVELD, 2015), and 3,300 km^2 through to 2020 (GLASS, 2013). Jaccoud and Villela (2013) estimated 6,000 km^2 of oil palm crops would be necessary to meet domestic demand in 2022. Based on that demand context and Villela (2014), the land demand for the scenarios was assumed to reach 10,000 km^2 by 2030 (Table 2).

Table 2 | *S1* (Reference) and *S2* (Sustainable) scenario assumptions based on several studies (BENAMI *et al*., 2018; BRANDÃO *et al*., 2021; BRANDÃO; SCHONEVELD, 2015; BRITO, 2017; GLASS, 2013; JACCOUD; VILLELA, 2013; LAPOLA *et al*., 2010; VIEIRA *et al*., 2014; VILLELA, 2014).

Scenario S1	*Scenario S2*
Land demand of 10,000 km2 up until 2030 (BRANDÃO; SCHONEVELD, 2015; GLASS, 2013; JACCOUD; VILLELA, 2013; LAPOLA et al., 2010; VILELLA, 2014)	Land demand of 10,000 km2 up until 2030 (BRANDÃO; SCHONEVELD, 2015; GLASS, 2013; JACCOUD; VILLELA, 2013; LAPOLA et al., 2010; VILELLA, 2014)
Commitment to deforestation reduction is not always fulfilled (VIEIRA et al. 2014); 20% of native forest is converted on private properties (BRITO, 2017)	Deforestation is forbidden, only degraded and deforested land is used (ALMEIDA et al., 2020; BENAMI et al., 2018; FURUMO; AIDE, 2017; WICKE et al., 2011)
Monoculture cultivation system	The monoculture cultivation system is avoided and replaced by intercropping techniques, favouring social inclusion; suitable for areas smaller than 0.1 km2 (ALMEIDA et al., 2020; BRANDÃO, 2019; BRANDÃO; SCHONEVELD, 2015; BRANDÃO et al., 2021)
Only the current producing municipalities are considered for the expansion due to the already implemented infrastructure	Other municipalities are considered

Source: Elaborated by the authors.

Based on Villela (2009, 2014) and IPCC Guidelines for National Greenhouse Gas Inventories (2006, 2012), the carbon release values were adopted for GHG emission calculations using the data organized in an Excel spreadsheet: GHG_r (reduction) = GHG_e (emission, fossil chain) – GHG_e. The models are the simplified calculation of the current model that favours market practices and product logistics close to the highways. Therefore, the discussion based on the analysis considers this limitation when analysing palm oil production and deforestation.

The land-use areas for each municipality, cross-checked with ZAE data. In addition, based on the analyses for scenario *S2*, new areas for oil palm expansion are proposed. As mentioned in the introduction, the ZAE has mapped the more suitable areas for palm oil production in Pará, according to the following land classifications: preferential, regular, marginal, not mapped, and not suitable; and considered two levels of development, B and C. Level B corresponds to agricultural development with fewer technology applications, whilst C represents a more highly technological approach to agriculture. The ZAE identifies the most suitable areas for planting these crops whilst taking into consideration the climate and soil characteristics, and the locations of native vegetation areas, conservation areas, Indigenous territories, and protected areas (BRASIL, 2010).

3 RESULTS AND DISCUSSION

3.1 CONCEPTUALIZING THE REFERENCE (S1) AND SUSTAINABLE OPTION (S2) SCENARIOS FOR GHG EMISSIONS

Scenarios are important tools to support public policy development. This approach is not intended to predict the future but to study various options for possible adoption and prepare palm oil stakeholders to take action to avoid negative impacts in the expansion process (MARCIAL; GRUMBACH, 2006). Scenarios are being used in climate change research according to the following classification: Business as Usual or reference situation, and other alternative scenarios that require different and innovative actions. Therefore, scenario development for palm oil is an important approach to study alternatives for the future and is being used for bioenergy expansion and feasibility research, aiming at reducing CO_2 emissions from land-use conversion and at fostering regional development (SACHS, 2007).

The conversion of native forests into palm oil plantations, which has been observed in Indonesia and Malaysia in recent years, causes the release of huge amounts of CO_2 into the atmosphere. However, the conversion of deforested and degraded land into palm oil plantations releases substantially less CO_2. That difference is associated with the role of soils as a carbon reservoir and is strongly dependent on land use and management practices. Native forests have a greater amount of stored carbon than areas of degraded vegetation. When land is converted to another use, carbon is released into the atmosphere, contributing to the greenhouse effect (FARGIONE *et al*., 2008; GIBBS *et al*., 2008; IEA, 2009; LAPOLA *et al*., 2010; SCARLAT; DALLEMAND, 2011). Brinkmann (2009), IPCC (2006, 2012) and Villela (2014) have reported that the carbon stocks contained in the soil and biomass of native forest and degraded land are, respectively, 174.7 tonnes C/ha and 49.2 tonnes C/ha. According to several studies (ALMEIDA *et al*., 2020; BERNOUX; VOLKOFF; CERRI, 2002; HASSAN *et al*., 2011; SAATCHI *et al*., 2011; SISTI *et al*., 2004; SOMMER; DENICH; VLEK, 2000), native forest carbon stocks are approximately 158 tonnes C /hectare, whilst the soil carbon stocks of degraded land average 52 tonnes C /hectare. The carbon stock of an oil palm crop is estimated to vary between 35 tonnes C/ha and 55 tonnes C/ ha (BRINKMANN, 2009; CARLSON *et al*., 2012; GERMER; SAUERBORN, 2008; HENSON; RUIZ; ROMERO, 2012; IPCC, 2006, 2012; YUI; YEH, 2013).

According to the IPCC (2006, 2012), a mean carbon stock value can be converted into units for emissions into the atmosphere by multiplying the value by 44/12, that is the ratio between the molecular weight of CO_2 and the atomic weight of C. Therefore, values, previously calculated by Villela (2009) and used as a basis to develop the scenarios calculations in this paper, are:

"Native forest conversion to oil palm crop, carbon release = 90.66 kg CO_2/ GJ

Degraded land conversion to oil palm crop, carbon release = - 79.06 kg CO_2/ GJ"

The first scenario (*S1*) was a Reference that limits the new forest conversion to palm crop to 20% on any given landholding in compliance with the Brazilian Forest Law (BRITO, 2017), even though there are major challenges in the determination of what is legally convertible or not in the management of secondary forests (BRANDÃO *et al*., 2021; VIEIRA *et al*., 2014). Based on that assumption, if the legal limit of 20% of the forest land on properties is converted to plant oil palm it is estimated to release 44,414 t CO_2/km^2, whilst the conversion of degraded land only releases an estimated 2,049 t CO_2/km^2.

These results can provide elements to orientate oil palm development, considering its indirect influence on other land uses. Despite the concern that developing pasture lands into oil palm may have induced cattle-raising activity to relocate to the forest frontier, and thus resulted in indirect deforestation (BENAMI *et al*., 2018; LAPOLA *et al*., 2010), our results may be overestimated, since intact forest and secondary vegetation conversion have been at a much lower rate than in other tropical regions of oil palm expansion (ALMEIDA *et al*., 2020; BENAMI *et al*., 2018; FURUMO; AIDE, 2017; WICKE *et al*., 2011).

The second scenario (*S2*) is a sustainable option, following the Sustainable Palm Oil Production Program and ZAE recommendation to only convert deforested and degraded land to oil palm crops. The identification of degraded land that is suitable for oil palm cultivation is at the core of sustainable expansion. In this scenario, the conversion of deforested and degraded land is estimated to release 2,049 t CO_2/km^2.

The GHG emissions under the *S1* and *S2* scenarios were presented as the total emissions of GHG from land-use conversion under the two scenarios up until 2030.

The conversion of 20% of land from native forest to palm cultivation, in the *S1* scenario, results in GHG emissions of 60.10^6 t CO_2 eq. in the year 2030, whilst the emissions for the *S2* scenario (no conversion of native forests) were calculated as 302.10^6 t CO_2 eq, less than the GHG emissions in the S1 scenario. Note that even in the *S2* scenario, deforestation is still considered a risk because the Sustainable Palm

Oil Production Program requirements do not guarantee by law that oil palm cultivation will be placed in deforested and degraded land. In addition, only the current 33 producing municipalities near Belém, the capital of the state, are considered for expansion because the infrastructure for palm oil production already exists so there are no extra investments required to create new processing plants (JACCOUD; VILLELA, 2013).

Scenario *S2* follows sustainable models of development, proving that palm tree cultivation on deforested and degraded lands can reduce the GHG emissions from land-use conversion, further reinforcing the benefit of reducing the level of deforestation for bioenergy purposes.

Both scenarios were created to reflect two current situations, without considering different decision-makers strategies for different uses of degraded areas or variations in deforestation monitoring. Therefore, these scenarios mainly serve to visualize different situations that could support the Sustainable Palm Oil Production Program.

3.2 SCENARIOS FOR PALM OIL PRODUCTION CONSIDERING THE SPATIAL DISTRIBUTION OF LAND-USE

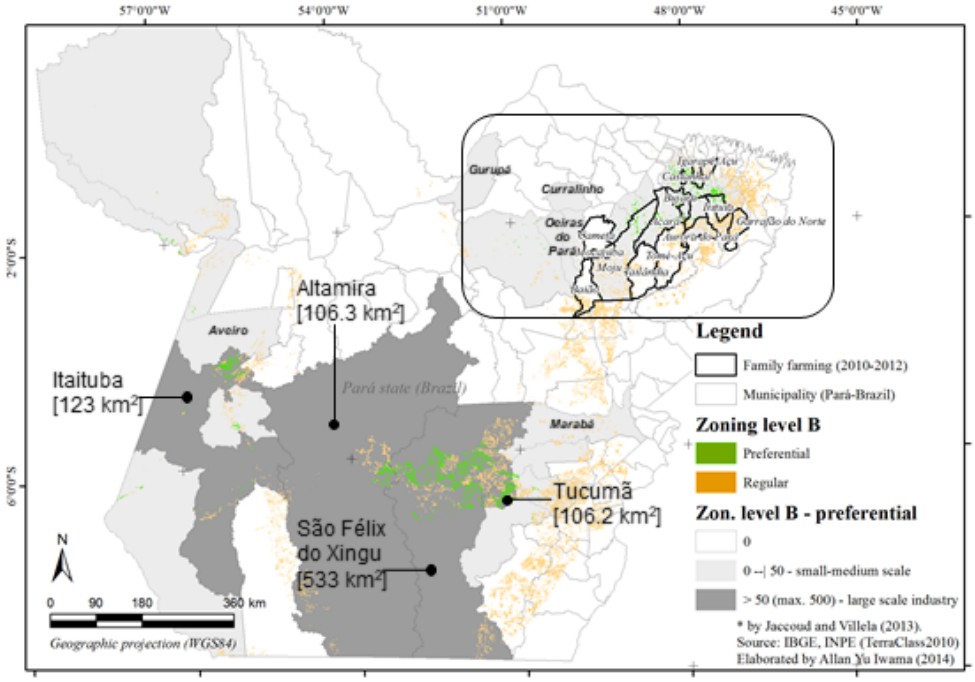
Considering the *S1* scenario assumptions, palm oil production places considerable pressure on land use because the focus is on the 33 municipalities that already produce palm oil, which corresponds to the aforementioned 2,882.97 km^2 of degraded and deforested land mapped by TerraClass (of the entire 27,414.02 km^2 in Pará State). If only this amount of land is available, other lands that are not deforested or degraded will likely be used for expansion. However, there is sufficient degraded land that could be used for expansion located outside the producing municipalities. Land pressure is reduced under the *S2* scenario since those other lands could be used for expansion.

The *S1* scenario represents the current production model, which corresponds to a non-sustainable option. Despite the low forest conversion to oil palm plantation (BENAMI *et al*., 2018), there is a potential deforestation risk insofar as landowners may legally convert 20% of a given property (BRITO, 2017).

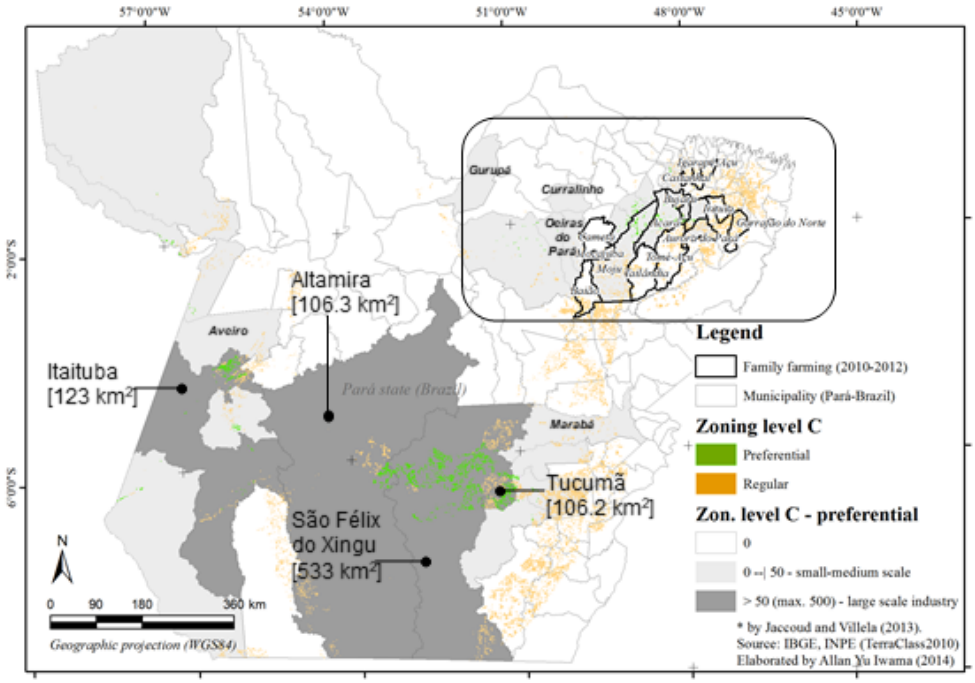
Conversely, the *S2* scenario represents a sustainable option due to the non-existence of deforestation to make way for palm oil crops, and the availability of sufficient land to meet the required demand for expansion. However, it should be considered that the use of more remote lands for production can create extra costs associated with changes in the palm oil production model, such as the construction of new processing plants in remote areas. The new infrastructure will be required because the available degraded and deforested lands are scattered throughout the state and outside the current producing municipalities (VILLELA, 2009, 2014). New processing plants can cause economic and environmental impacts and social conflicts in association with the development of infrastructures such as roads, the demand for new workers, the relationship with local communities, and even food security issues because small farmers are not capable of growing food crops together with oil palm, and consequently, food prices tend to increase (GLASS, 2013; HUNSBERGER *et al*., 2014; STATTMAN; MOL, 2014). An important factor influencing oil palm expansion is road proximity because new crops are more likely to be established near roads (YUI; YEH, 2013).

Figure 3 depicts the TerraClass land classification for the municipalities in Pará State, cross-referenced with the ZAE. The preference (of producers) for oil palm cultivation in the preferential zoning areas, represented by scenario *S1*, can result in the overexploitation of these regions, causing soil erosion, deforestation and losses of biodiversity, as well as impacts on local communities. There is enough land located in preferential zones for palm oil expansion available outside of the producing municipalities, at both B and C development levels that can be used for expansion in scenario *S2* conditions.

Figure 3 | Deforested/degraded land, cross-referenced with the ZAE: (a) management level B (low technology) and (b) management level C (high technology) and municipalities with > 100 km² of available degraded land in ZAE-designated preferential areas for oil palm (São Félix do Xingu, Itaituba, Altamira and Tucumã). Family farming refers to municipalities registered in the palm oil programme in that category (GLASS, 2013).



(a)

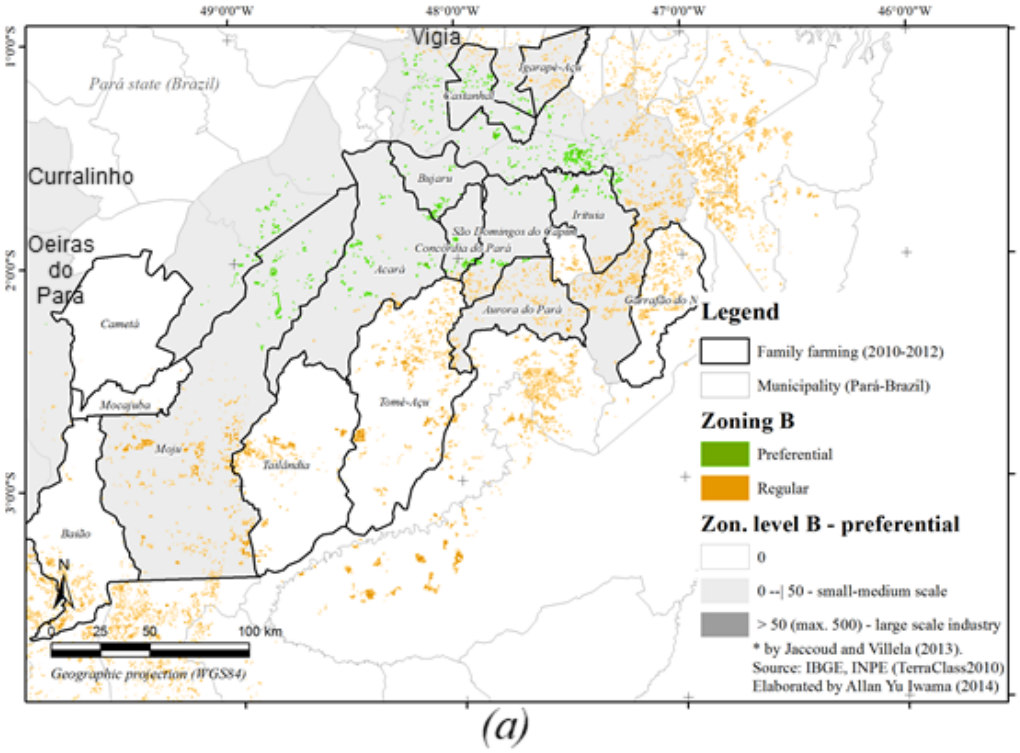


(b)

Figure 3 also shows that potential areas of land larger than 100 km² are located in just a few municipalities (São Félix do Xingu, 533 km²; Itaituba, 123.3 km²; Altamira, 106.3 km²; and Tucumã, 106.2 km²), including both ZAE levels, B and C (Figures 3a and 3b).

The mapping process shows that there are 862 km² of areas in the Preferential zoning category for smallholder oil palm crops, and 6,729 km² of degraded and deforested land in Regular zoning areas for the same crops. Therefore, altogether we found 7,591 km² of land available for small farmers (Figure 3 and Figure 4).

Figure 4 | Deforested/degraded land, crosschecked with ZAE: (a) land in municipalities in north-eastern Pará State (smallholder farming) under management level B and (b) land in municipalities in north-eastern Pará State under management level C.



Source: IBGE (2013) and TerraClass. Family farming municipalities are those registered as such in the palm oil programme (GLASS, 2013).

There are municipalities with areas of potential land ranging from 0-50 km2 located in the north-eastern part of Pará State (Figures 4a and 4b), with areas of varying ZAE management levels. Areas with less than 0.1 km2 (or 10 ha), suitable for small farmers are proposed for the S2 scenario. Municipalities with degraded land of less than 0.1 km2, Gurupá, Curralinho, Oeiras do Pará, Vigia and Aveiro show potential for small farmers and should be considered for palm oil production and small farmer activities expansion as well. Municipalities that are integrated with small farmers (family farms) are already notoriously subject to social conflicts (Figures 4a and 4b). According to Glass (2013), small farmers have improved their income by growing oil palm; however, their quality of life is still subject to question mainly because of the inconsistency between the initial discourse in the oil palm contracts and the later practices (TAVARES; MOTA, 2020).

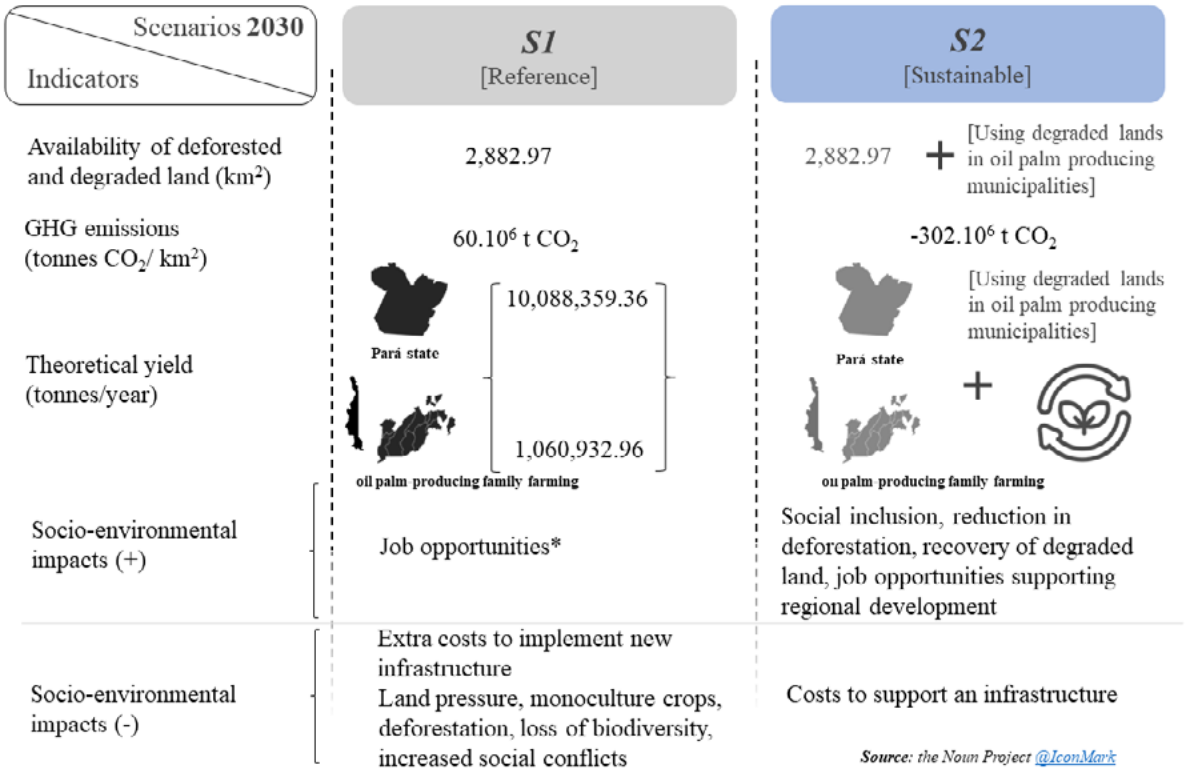
The use of degraded and deforested areas of land has implications beyond GHG emissions. A number of these areas are smaller than 0.1 km^2 and that can pose a challenge because they are fragmented, and it is costly to maintain small crops of oil palm. On the other hand, the use of degraded land for the expansion of palm oil production also has the potential for positive environmental impacts (UNEP, 2007), including recuperating the productive capacity of the degraded land, restoring its function as an ecosystem services provider (LI *et al*., 2019) and promoting an increase in the carbon stock of the cultivated land. In addition, small and scattered areas of degraded lands could be cultivated by small farmers, thereby improving livelihoods in rural areas by providing social and economic benefits (CBD, 2009). Examples of other problems that the cultivation of oil palm on degraded land can present include difficulties associated with the degradation of growing conditions, which may cause a requirement for greater amounts of fertilizers and longer periods to improve productivity because of the lower yields compared to production on newly deforested areas, and there may be difficulties associated with land ownership issues (WICKE *et al*., 2008).

To complete the land availability analysis, the potential yield from oil palm cultivation was calculated based on the available area and an annual palm oil yield of 3.68 tonnes per hectare (368 tonnes/km^2) (BRITO, 2007). We determined that the potential yield is 10,088,359.36 tonnes/ for deforested and degraded land in Pará State. In 2019, the yield was 2,543,814 tonnes, while in the palm oil-producing municipalities, the potential yield is 1,060,932.96 tonnes/year. If the demand for palm oil production continues to increase until 2030, other lands could be converted to oil palm cultivation, so it is necessary to keep a close watch on adherence to principles of sustainability and the associated social conditions (BRANDÃO *et al*., 2021; TAVARES; MOTA, 2020).

Thus if, as in the case of the S1 scenario, land conversion is not restricted to the use of degraded/ deforested land only, there are serious are risks of deforestation, biodiversity losses and impacts on local communities occurring. Under the *S2* scenario, however, the land conversion target is achieved sustainably. The *S2* scenario corresponds to a possibility for the near future that envisages a real commitment to sustainable development – Figure 5.

This paper uses a spatially explicit exploratory model, considering the edaphoclimatic conditions and the availability of land. This limitation implies the spatial distribution of municipalities that mainly serve capital's model and arguments to prioritise areas close to the roads, facilitating production and logistics. Despite the simplicity of the model for predicting the expansion of oil palm and the calculation of emissions, it provides elements for the discussion on the expansion of oil palm and degraded land use, especially with the incentives instituted by the Biodiesel Law in 2005 that started oil palm investments in Pará, focused largely on the municipalities south of Belém like Tailândia, Moju, Tomé-Açu, Acará, Concórdia do Pará, and São Domingos do Capim and led by large national and international corporations such as Biopalma, the ADM and a joint venture between Petrobras and Galp (BRANDÃO; SCHONEVELD, 2015).

Figure 5 | *Scenarios S1 (reference) and S2 (sustainable) to 2030 and socio-environmental impacts*



4 CONCLUSIONS

Scenarios for palm oil expansion were evaluated to support the development of a more sustainable path for palm oil expansion. Under the *S1* scenario, as a result of the conversion of native forest conversion to oil palm cultivation, accumulated GHG emissions would reach 60.10^6 t CO_2 by 2030. However, the *S2* scenario, based on the conversion of degraded and deforested land to palm, limits GHG emissions in 2030 to 302.10^6 t CO_2 less than the amount released in the *S1* scenario. These results show that there is a need for the development of new infrastructure for additional oil processing plants in the state to place palm oil crops in other lands outside the present producing areas and reduce the GHG emissions and other environmental impacts related to deforestation. Besides, the amount of degraded and deforested land located within the current palm oil-producing municipalities is only sufficient for the projected level of expansion in 2020. Therefore, under the *S1* scenario, other land areas, including native forest and protected areas, are at risk of being used to accommodate oil palm expansion, leading to further deforestation and various environmental and social impacts, showing that *S2* scenario is a sustainable option. In addition, the use of deforested and degraded land can help promote the social inclusion of small farmers and local communities, creating job opportunities and improving income levels, thus supporting regional development (BRANDÃO, 2019; BRANDÃO *et al*., 2021; CORDOBA *et al*., 2019; TAVARES; MOTA, 2020). However, field assessments are necessary to evaluate the processes required for the development of these degraded land areas.

The results also demonstrate the need for sound land-use policies for planning and monitoring the expansion of palm oil production, and the need to assess the quality and potential of lands that can be used for this expansion. In addition, the results reinforce the suitability of the *S2* scenario as an alternative for the sustainable development of palm oil production in Brazil. The development of scenarios for palm oil expansion based on the support and guidelines of the ZAE and the Sustainable Palm Oil Production Program has proved to be a beneficial tool for environmental planning. The *S2* scenario is a better option

to follow if Brazil wants to become a leader in sustainable palm oil production. However, these scenarios require a transformation of the current production model for palm oil and depend on the support of public policies, especially regarding land-use dynamics, as pointed out by other studies (ALMEIDA *et al*., 2020; BENAMI *et al*., 2018; BRANDÃO, 2019; BRANDÃO; SCHONEVELD, 2015; BRANDÃO *et al*., 2021).

Further research on the development of degraded lands is required as well as on social aspects related to smallholder production. Environmental education programs must be developed involving all stakeholders to achieve sustainable palm oil development in Brazil.

ACKNOWLEDGEMENTS

The authors wish to thank the CNPq for the research grant 141570/2010-5 and ANID/FONDECYT 3180705/2018. They also thank the reviewers of the manuscript and MC Nicholl for revising the English language.

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Historical trajectory and resilience in an agro-extractive settlement project in the Lower Tocantins River, Pará, Brazil

Trajetória histórica e resiliência em um projeto de assentamento agroextrativista no Baixo Rio Tocantins, Pará, Brasil

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doi:10.18472/SustDeb.v12n2.2021.34091

Received: 14/09/2020
Accepted: 06/07/2021

ARTICLE – VARIA

ABSTRACT

The São João Batista riverside community experienced a golden phase in the production of cachaça from sugar cane (*Saccharum officinarum* L.). It underwent a period of decay around 1975 and, in 2004, became an Agro-extractive Settlement Project (PAE), with an economic system based on the exploitation and commercialization of açaí (*Euterpe oleracea* Mart.). This study analyzes the resilience of PAE São João Batista, Abaetetuba, Pará, from the establishment of sugar cane mills to the transition of their economic system to the exploitation and commercialization of açaí. It was based on field research conducted with 141 riverside dwellers employing semi-structured interviews. The adaptive cycle was built up, from which resilience was analyzed. The growth of the açaí fruit market identifies the community's point of resilience. The sugar cane-açaí economic system transition enabled riparian populations to experience changes and to create conditions for reorganizing themselves as a settlement.

Keywords: Adaptation. Uses of biodiversity. Socioecological System. Abaetetuba.

RESUMO

A comunidade ribeirinha São João Batista vivenciou uma fase áurea da produção da cachaça de cana-de-açúcar (Saccharum officinarum L.). Tendo passado por um período de decadência por volta de 1975, veio a se tornar um Projeto de Assentamento Agroextrativista (PAE) em 2004, agora com seu sistema econômico baseado na exploração e comercialização do açaí (Euterpe oleracea Mart.). Este estudo analisa a resiliência da comunidade do PAE São João Batista, Abaetetuba, Pará, em função do estabelecimento de engenhos de cana-de-açúcar e a transição do sistema econômico para a exploração e comercialização do açaí. O estudo se baseou em pesquisa de campo com 141 ribeirinhos por meio de entrevistas semiestruturadas. Construiu-se o ciclo adaptativo, a partir do qual foi feita a

análise de resiliência. O crescimento do mercado do fruto de açaí assinalou o ponto de resiliência da comunidade. A transição cana-açaí efetivou a capacidade dos ribeirinhos de experimentar mudanças e criar condições para se reorganizarem enquanto assentamento.

Palavras-chave: Adaptação. Usos da biodiversidade. Sistema Socioecológico. Abaetetuba.

1 INTRODUCTION

Amazonian socioecological landscapes were shaped by human action in different intensities, and the use and exploitation of their natural resources have led to a stage of conflicts and struggle involving various actors and interests (ATHAYDE *et al*., 2016). Among these actors are the traditional populations who socially reproduce their ways of life by interacting with the environment.

In the floodplains of the Amazon estuary, *ribeirinhos*[1], or riparian communities, have established systems of utilizing natural resources that combine various subsistence activities based on family labour and use of low-impact technologies derived from traditional knowledge (FERREIRA, 2012; LIMA; POZZOBON, 2005). Concerns about recognition of territorial rights of traditional populations and sustainability of territories and production systems induce the creation of rural territories of agro-extractive identity, which culminated with the advent of Agro-extractive Settlement Projects (Brazilian acronym: PAEs) as units of conservation of sustainable use, fulfilling the demands of the environmental movement and the land claims of social movements (ARAÚJO *et al*., 2019).

To understand how communities are affected by and respond to disturbances, complex systems theory has been applied through the representation of socioecological systems (Brazilian acronym: SSE). In the Tocantins River, in the large area affected by the Tucuruí dam, Bentes *et al*. (2014) showed that some communities have been organizing themselves through fishing agreements, towards better living conditions. This indicates that the changes directly or indirectly associated with habitat destruction, climate changes and overexploitation of biodiversity (SILVA *et al.*, 2020) have been hitting human groups that greatly depend on natural resources through their effects on socioecological systems (HE; SILLIMAN, 2019).

PAEs may be regarded as a model of socioecological system where the social system includes farmers, extractors and fishermen, and their respective modes of production, institutions, production chains, social processes and relationships. The ecological system is addressed in different scales, ranging from the several terrestrial and aquatic environments to the unit of species extracted from these settlements. The social and ecological systems interact with each other, resulting in an "agro-extractive system" within socioecological systems on a wide scale, such as the international market (of açaí, for instance), biomes, global climate, etc. (OSTROM, 2009).

Under such a perspective, there is the resilience approach, whose society-nature interface is regarded from the feedback relationships that characterize the SSE (LINDOSO, 2017). The resilience of a system is defined as the ability of that system in dealing with disturbances while maintaining its functions (FOLKER *et al*., 2004). In the Amazonian context, Buschbacher (2014) uses the word resilience as meaning "the ability to deal with uncertainties, changes and surprises through adaptation, learning and self-organization". Through the adaptive cycle (HOLLING; GUNDERSON, 2002), one can describe how change patterns and processes over time occur in systems.

In that context, a historical review of the access to land and the survival strategies of riparian communities concerning the effects of environmental events and their consequences as well as their ways to adapt to the capitalist market allow for an analysis of their socioecological resilience and the possibilities of long-term planning. Particularly for the traditional Amazonian populations, the ability of socioenvironmental systems to respond and adjust to their milieu demonstrate their role in the conservation of the Amazonian Forest vis-à-vis global environmental changes, for their power of mediation of political transformations in various scales and territories (FLEURY *et al*., 2019).

This paper analyzes the trajectory and resilience of PAE São João Batista, in the municipality of Abaetetuba (State of Pará), based on some elements of socioecological systems and resilience approaches (HOLLING, 2001; WALKER *et al*., 2006). By considering the adaptive cycle as a heuristic model, this approach has been employed to explore the dynamics and change trajectories of SSEs since the establishment of sugar cane mills in 1930 and the transition of the economic system to the exploitation and commerce of açaí. Resilience trends were analyzed in the light of the dimensions of social, economic and environmental capitals (SALVIA; QUARANTA, 2015), taking into account the different phases of the adaptive cycle.

2 MATERIAL & METHODS

2.1 STUDY AREA

The Municipality of Abaetetuba (01º43'24" S, 48º52'54" W) has a population of 141,100 inhabitants (IBGE, 2010) and its economy is mainly based on fishing, extractive gathering – foremost, of açaí) and agriculture (BARROS, 2009). Together with ten other municipalities, it constitutes the Lower Tocantins region, and its history is associated with the process of colonization of Amazonia, which is characterized by a model of economic integration with international capitalism (MACHADO, 2008).

From a socioenvironmental standpoint, Abaetetuba presents an expressive diversity punctuated with knowledge, memories, activities, symbologies, customs and a routine intertwined with the spaces of rivers, forests and floodplains (POJO; ELIAS, 2018). The municipality includes 72 islands that are geographically located in the lower course of the Tocantins River, at its confluence with the Pará River, in the estuary. The region is predominantly formed by floodplains and inhabited by riparian communities and *quilombolas* who are more or less intensely linked with the city, depending on their respective distance from urban centres (BARROS; SILVA, 2013).

For this study, we chose the island of Campompema (Figure 1), Pará, where the PAE São João Batista is located. The selection of this area is justified because it is one of the first localities where an Agro-extractive Settlement Project (PAE) was implemented in the Amazon, as part of the set of land recognition project models created in 2004 as a way to boost economic and environmental actions in floodplain areas historically occupied by traditional populations.

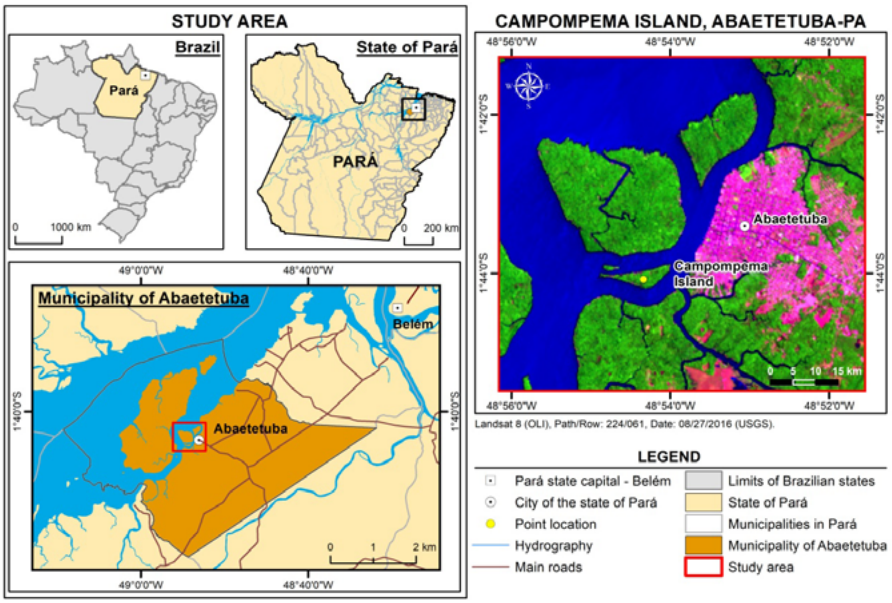

Figure 1 | Study area.
Source: Elaborated by the authors.

PAE São João Batista was created through Ordinance Incra/SR (01)/Nº 27 of 27 July 2004, published in the Diário Oficial da União [Official Gazette of the Union] Nº 146 of 30 July 2004, Section I, comprising an area of 471,961ha (INCRA, 2017). This settlement is the result of the struggles of local social movements to achieve land regularization. Initially, the riverside dwellers received the Sustainable Use Authorization Term issued by the Union Heritage Secretariat, this document being a facilitating element for access to government social benefits and effective for proving residence (IPEA, 2015). The riverside population of PAE São João Batista have developed survival strategies based on the use of natural resources, both related to fishing and extraction of forest products, to adapt to the political, social, environmental and economic changes. The São João Batista settlement experienced the golden phase of sugar cane cachaça (*Saccharum officinarum* L.) production in the 1960s; it had its moment of decay 15 years later, and in 2019, as a rural settlement, it starts to enjoy an economic system based mainly on the exploitation and commercialization of the açaí fruit (*Euterpe oleracea* Mart.), which has a global market.

2.2 DATA COLLECTING

To conduct this analytical-descriptive research meetings were initially held with the community leadership for exposure of the nature of the work and authorization of the research through the Written Informed Consent Form (WICF). Subsequently, the documents resulting from this previous moment were forwarded to Plataforma Brasil for evaluation. The Research Ethics Committee of the Health Sciences Institute of the Federal University of Pará (UFPA) approved its execution under CAAE 74844417.4.0000.0018.

The study included field research conducted from March to August 2018 in PAE São João Batista. The subjects involved in the research were the residents of the settlement area, totalling 141 interviewees (49% of the population residing in the PAE). The age of the interviewees ranged from 18 to 59 years, with a higher percentage (67%) of women.

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Semi-structured interviews aimed at probing the population's way of life and identifying historical events and main factors influencing the trajectory of the establishment of the settlement. The interviews were carried out from 7 AM to 5 PM at the interviewees' residences, with a maximum of three interviews per day. As land ownership and access to natural resources in the São João Batista community are subjected to the rules of the Agro-extractive Settlement Project, the interviewers were aware that some questions could cause some discomfort due to concerns of financial or material loss. Therefore, interviewees were allowed to interrupt the questioning at any time, ensuring their autonomy and free will.

The interviewees' reports are referenced throughout the text with the initial letters of their name and age, guaranteeing the confidentiality of their identity. Subsequently, research was carried out in scientific literature (articles, books and institutional sites) to verify the political interventions in the settlement, in addition to historical records.

2.3 ADAPTIVE CYCLE CONSTRUCTION

Holling (2001) proposes a four-phase adaptive cycle model, where a system grows slowly (exploration phase), accumulates wealth for a sustained period (conservation phase), collapses (release phase), and rapidly reorganizes (reorganization phase), allowing it to grow in an identical or different configuration (HOLLING; GUNDERSON, 2002).

The identification of the four phases of the adaptive cycle: r – exploitation; k – conservation; Ω – release and α – reorganization was carried out based on the interviews and literature consultation, going through the adaptive cycles of sugar cane and in that of açai, from 1930 to 2018. Thus, it would be possible to cover the reconstruction of the historical memory of local actors, even because this period marked the transition from sugarcane agriculture to the management of one of the most important species of Amazonian extractivism, which participates in the global market.

To describe the phases of the adaptive cycle, the assumptions detailed in Table 1 were considered, with the attribution of values referring to social, economic, and natural capitals, with 1 (one) for the criteria considered strong and 0 (zero) for those considered weak, according to Salvia and Quaranta (2015). Strong capital ensures a high level of resilience potential, as well as, conversely, weak capital signals an inability of the SSE to adapt, transform and respond overall to change, thus influencing the degree of resilience of the system. The criteria were identified by combining the components that would indicate whether the economic, social and natural capital would be well or poorly developed in the settlement.

Table 1 | Criteria for assessing resilience in the various phases of the adaptive cycle in the cultivation of sugar cane and açaí in PAE São João Batista, Abaetetuba, Pará.

Phases (years)	*Capital*			*Description*
	Social	*Economic*	*Natural*	
Exploitation (r) 1930 - 1950	Presence of united community, high diversity (1)	Riparian populations with a wealth of resources; high commercialization (1)	Planting without threatening local biodiversity; species such as açaí managed for survival (1)	Strongly developed socioeconomic and environmental capital (1)
	Absence of united community, low diversity (0)	Riparian populations without a wealth of resources, highly dependent on outside financing; low commercialization (0)	Monoculture; landscape simplification; soil degradation (0)	Poorly developed socioeconomic and environmental capital (0)
Conservation (k) 1960 - 1973	Good communication between social actors; investment in infrastructure and institutions for the education of children and youngsters (1)	High productivity; production flow; generation of employment and income for families (1)	Low degradation of forest and soil; preservation of water resources (1)	Strongly developed socioeconomic and environmental capital (1)
	Lack of communication between social actors; lack of investment in infrastructure and institutions for the education of children or youngsters (0)	Low commercialization of resources; difficulties in the production flow and the generation of employment and income (0)	High degradation of forest and soil; water resources depleted (0)	Poorly developed socioeconomic and environmental capital (0)

Phases (years)	Capital			Description
	Social	Economic	Natural	
Release (Ω) 1975 - 1987	High diversity; incorporation of traditional techniques of cultivation; support for community social programs (1)	High product commercialization (1)	Low exploitation of açaí (1)	Strongly developed socioeconomic and environmental capital (1)
	Low diversity; technological precariousness; lack of support for community social programs; precarious employment situation; job informality (0)	Low product commercialization (0)	Sharply increased process of açaí exploitation (0)	Poorly developed socioeconomic and environmental capital (0)
Re-organization (α) 1990 - 2004	The ability of the organization in networks and key institutions such as co-operatives, associations; the presence of consulting services for riparian communities (1)	The low requirement to import resources for community survival; the extractive gathering of plants as a source of income and job assurance (1)	Natural resources available for exploitation: good water and soil quality (1)	Strongly developed socioeconomic and environmental capital (1)
	The inability of organization in networks and key institutions such as co-operatives, associations; absence of consulting services for riparian communities (0)	The high requirement to import resources for community survival (0)	Natural resources unavailable for exploitation: poor water and soil quality (0)	Poorly developed socioeconomic and environmental capital (0)
Exploitation (r) 2007 - Current	Social mobilization: the presence of schools and services for riparian communities; social integration of families (1)	High resource commercialization; participation in programs of financial support; acceptance in markets (1)	Good soil and water quality; preservation of local biodiversity (1)	Strongly developed socioeconomic and environmental capital (1)
	Absence of social organization; lack of schools and services for riparian communities (0)	Low resource commercialization; lack of participation in programs of financial support; rejection in markets (0)	Monoculture; soil degradation; poor water quality; local biodiversity threatened (0)	Poorly developed socioeconomic and environmental capital (0)

Source: Elaborated by the authors.

Changes in the PAE were analyzed in light of the dynamics that shaped the social, economic, and natural capitals described in Table 1. The analysis of resilience trends, extrapolated from the trajectories of the three different types of capitals, led to the construction of the adaptive cycle from 1930 to 2018 for the sugar cane cultivation and açaí production sectors. Based on the criteria presented in Table 1 and, subsequently, based on the levels attributed to the capital (strong or weak), we obtained the valuation and indication of resilience in each phase of the adaptive cycle as Not Resilient = 0; Slightly Resilient = 1-2 and Resilient = 3. The resilience indicators incorporate the different phases of the adaptive cycle and can act as a barometer of overall resilience, because their presence suggests a resilient SSE, while their absence or disappearance suggests a loss of resilience and greater vulnerability to disturbances (CABELL; OELOFSE, 2012). The flowchart of the research with its steps is presented in Figure 2.

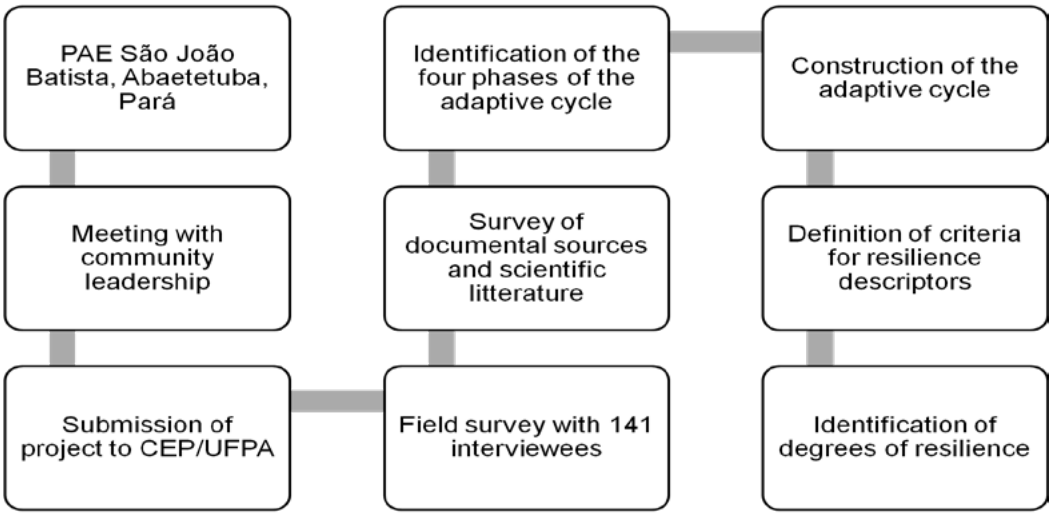

Figure 2 | Flowchart of the study in the PAE São João Batista, Abaetetuba, Pará.

3 RESULTS AND DISCUSSION

Along their historical trajectories (Figure 3), sugarcane and açaí were necessary resources for the socioeconomic reproduction of the riparian communities in the PAE São João Batista, because it was through them that the process of territorial occupation and exploitation of natural resources took place, as well as changes in land use.

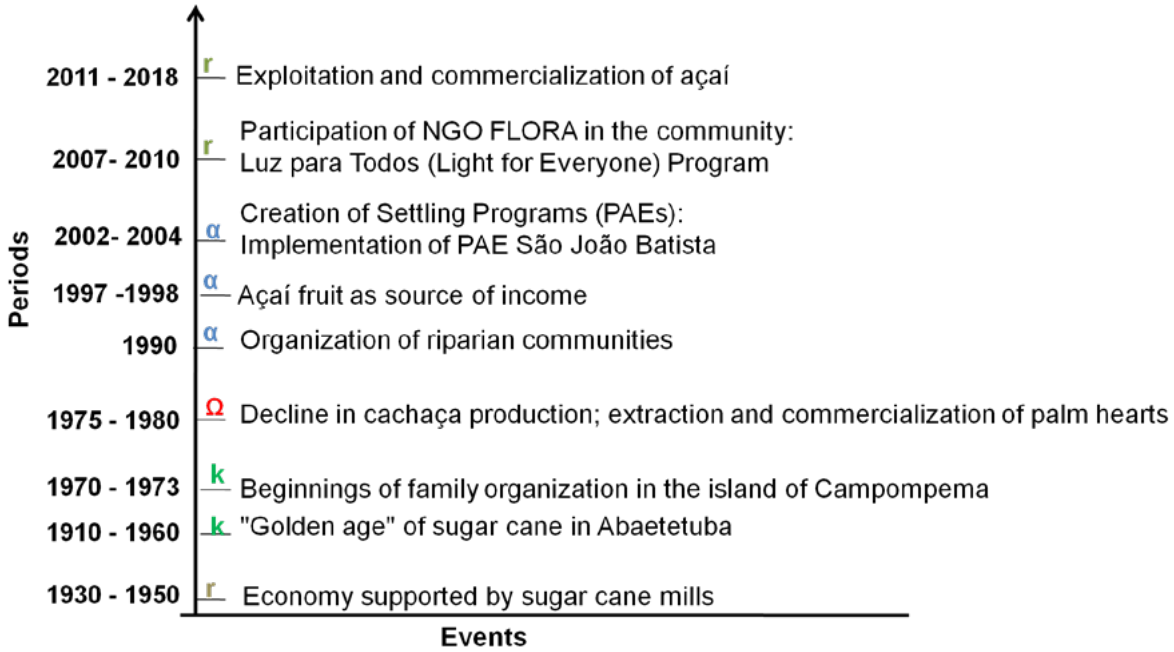

Figure 3 | Historical trajectory of the PAE São João Batista territory, based on the cultivation of sugar cane and açaí respectively.

3.1 PHASES OF THE ADAPTIVE CYCLES IN THE PAE SÃO JOÃO BATISTA

3.1.1 SUGAR CANE – EXPLOITATION (r)

In 1930 the riparian dwellers from the island of Campompema worked in the Santa Cruz sugar cane mill. It belonged to Mr Murilo Parente Carvalho, located next to the Abaeté River, which remained in operation until around the 1960s and controlled the economic, social and environmental aspects of their lives, described as follows: *"The Santa Cruz mill produced lots of cachaça and its profits supported our life here in the community* (B. L. S., 83 yo.). *"There were no açaí sales, they sold cachaça"* (R. N., 74 yo.).

Sugar cane sticks were cut in pieces of about 80cm in length and piled up in the field in bundles that were carried and tied up in lots of ten, forming a *frasqueira* of cane (ANDERSON, 1991). *Frasqueira* was a unit agreed between the sugar cane collector and the mill owner for commercial transactions. In many cases, this agreement occurred in the form of a deal by which the mill owner would offer the land and the worker with his labour (NAHUM, 2011). The cane collector would get some financing from the mill owner to prepare the land, plant the cane, keep it in condition and then cut down the yield.

In exchange for an *aviamento*[2] of a sugar cane plot (done with consumption goods available at the mill's store), the mill owner expected the cane collector to deliver his entire production. It was a person-to-person, informal arrangement that benefited only one-tenth of the farmers, and the workers without resources or *aviamento* were forced to become daily labourers (ANDERSON, 1991).

3.1.2 SUGAR CANE – CONSERVATION (K)

Together with other family mills, the Santa Cruz mill ensured the floodplain area population a stable income (ROGEZ, 2000), particularly in the 1960s, when the sugar cane yield had its "golden phase" in Abaetetuba. The increase in demand led to the installation of the first steam machines destined exclusively for the production of spirits (cachaça), whose quality was acclaimed all over the Pará State (MACHADO, 2008). However, the mills always operated following a primitive conception of production and economic relations and, over time, these means of survival declined.

In the 1970s, many workers resorted to the judicial system to claim their rights from the mill owners, and to avoid a larger social conflict, the State demanded the owners give away part of their lands in allotments to redress workers compensations (QUARESMA *et al*., 2015).

3.1.3 SUGAR CANE – RELEASE (Ω)

> Planting and commercialization of sugarcane started to decline in 1975, as *"it was slave work, I earned three thousand réis [three cruzeiros] a week, then Labor Justice came and closed down the mill"* (R. N., 74 yo.). For some, *"life in the mill was tiresome, only the owner had profits"* (J. M., 56 yo.). Indeed, intensive labour was predominant in the mills, and cachaça production underwent a crisis; workers were not paid government incentives and were harmed the worst (QUARESMA *et al*., 2015). Furthermore, the precarious conditions of the mills, the refusal to replace the *aviamento* system with more modern practices, technological unreliability and the introduction of new labour laws all contributed to the overall deterioration (MACHADO, 2008; NAHUM, 2011).

The activities in the mills declined, *"each of us began taking care of our plot"* (J. M., 56 yo.), and as some *ribeirinhos* would not accept the current situation and demanded improvements, between 1970 and 1973 meetings began to happen involving representatives of the Catholic Church to discuss family organization in Campompema island. *"Four residents were helped by the Diocese to create the community, they organized their families to be registered and be recognized* (B.L.S., 83 yo.), so the São João Batista Community was created. The role of the Church was determinant in this process of territorialization of riparian communities, as it developed theoretical and practical political constructions to raise consciousness for the real situations that unleash oppression (GONÇALVES *et al*., 2019).

The creation of the community coincided with the period of decline of the sugar cane production, a period in which the slowdown in the production of "cachaça" led the system to collapse, so the workers that depended on it were forced to look for alternative ways to survive, as *"There was nothing, it was a situation of dereliction"* (J. M., 56 yo.). Traditional food resources were exploited with increasing intensity: hunting became practically extinct, fishing did not bring much income; shrimp, which was a dietary complement, became subjected to predatory capture for resale; and whole açaí groves were cut down to sell the heart of palm to factories located in the estuary (ANDERSON, 1991). Indeed, the destruction of the varzea forests with acai palms was so intense that state intervention was necessary through Law n°6.576/1978, which banned the felling of açaí palm trees in the entire Brazilian territory – to little avail, as in 1980 the State of Pará became the main extractor and producer of canned hearts of palm in Brazil (MOURÃO, 2010).

3.1.4 RE-ORGANIZATION (α)

Intense exploitation of açaí forests was associated with the informality of the occupation, like the federal administration of the territory allowed riparian communities to become vulnerable to third-party activities (ALVES, 2016). However, from 1990 on the Land Pastoral Commission (Brazilian acronym: CPT), the Basic Ecclesial Communities (Brazilian acronym: CEBs), the Union of Rural Workers (Brazilian acronym: STTRs), the Fishermen's Colony and local associations got together to organize riparian communities towards recognition, demarcation and land titling (GONÇALVES *et al*., 2016).

Simultaneously to that process of organization, the production pattern of açaí would be altered from extractive to cultivated and/or directed management (FERREIRA, 2012). The growth of the açaí fruit market in the 1990s caused a positive effect on its preservation and conservation (TAVARES; HOMMA, 2015). In 1997 and 1998, that fruit was an important source of income, especially due to the increasing demand in markets beyond the region, which ended up favouring the Rural Settlement Projects (Brazilian acronym, PAs) in the islands around Abaetetuba in 2002 (FERREIRA, 2012; GONÇALVES *et al*., 2016).

The Agroextractive Settlement Projects (PAEs) anticipated the exploitation of areas provided with extractive riches through economically feasible, socially fair and ecologically sustainable activities in the Amazonian floodplains. In 2002-2004, populations that occupied or intended to occupy these areas would implement those activities (BRASIL, 1996). PAE São João Batista was implemented in 2004 in the island of Campompema, and one of its goals was to foster the productive chain of the exploited natural resources (ALVES, 2016).

3.1.5 AÇAÍ – EXPLOITATION (r)

During the exploitation and commercialization of sugar cane spirits (cachaça), açaí production was geared toward family survival: açaí fruit was collected and vines were cut off to ease its handpicking. The natural abundance of açaí palms was little affected by humans, to whom they supplied enough for their domestic needs, and management was restricted to backyard clumps where the fruit was collected (MARINHO, 2009). This state of affairs, however, began to change with the progressive market demand for açaí, which favoured the implementation of the PAE São João Batista in Campompema Island. According to locals, in 2007 and 2008 the non-governmental organization FLORA created a module of permanent planting of açaí palm for the riparian community to strengthen forest conservation. In 2010 Campompema island was included in the Program Luz para Todos (LpT-Light for All), created by the federal government (Decree 4.873/ 2003) to increase income and promoting the social inclusion of benefitted communities by providing access to electricity (FREITAS; SILVEIRA, 2015). This program brought an electric energy to 41 residences (among the interviewees) who managed to register in the PAE São João Batista. Others who missed their registration live on energy regularly supplied by Centrais Elétricas do Pará (Celpa). There are also small private energy suppliers, altogether summing up 100 families who can enjoy electrical energy.

The settlement also harbours the actions of institutions such as the Movement for the Ribeirinhos and Ribeirinhas of the Abaetetuba Floodplains (Brazilian acronym: Moriva), the Movement for the Ribeirinhos and Ribeirinhas of the Settlement Projects (Brazilian acronym: Moripa), churches, the PAE São João Batista Association. More recently the Abaetetuba Town Hall implemented a system of water supply and distribution to the residents that helped the exploitation and commercialization of açaí fruit in local and external markets. It is estimated that açaí is the main source of income for 77% of the rural population in northeastern Pará (SANTANA *et al*., 2012).

Likewise, the riparian community of the São João settlement have açaí as their basic source of income, which explains their appropriation of floodplain areas for management of açaí palm trees: it was found to be so in 75% of the analyzes family establishments. Management of floodplain forests for açaí production is done off-season (from January to July) and involves the felling of the tallest and least productive palm trees, cleaning the plot and then its enrichment with the planting of new açaí palm trees. During this off-season period, the source of income for the locals is the selling of artefacts, fish and shrimp in local marketplaces and also official government money transfer programs such as *Bolsa Família*[3].

The commercialization of açaí fruit is done in local marketplaces or through the Abaetetuba Fruit Farmers Co-operative (Brazilian acronym: Cofruta), created in March 2002, in which eight ribeirinhos of the settlement take part (an informant). Besides Cofruta, through the agro-extraction of açaí, the riparian communities aim to strengthen their production chain through access to microcredit and business advice. Thirteen per cent of *ribeirinhos* requested support from the Amazônia Florescer program (Amazonia Blossoming) of the Banco da Amazônia, so that a family could have resources to enhance the development of their extractive activities: for instance, 7% of the families were consolidating a partnership with the company “100% Amazônia” to be able to sell açaí at its best price.

3.2 ADAPTIVE CYCLE AND RESILIENCE OF THE PAE SÃO JOÃO BATISTA

The historical process of occupation of the PAE is associated with the community’s ways of life in interaction with the floodplain environment and the production of sugar cane and açai palm. The importance of the historical trajectory is shown in the adaptive cycle about these cultivations (Figure 4).

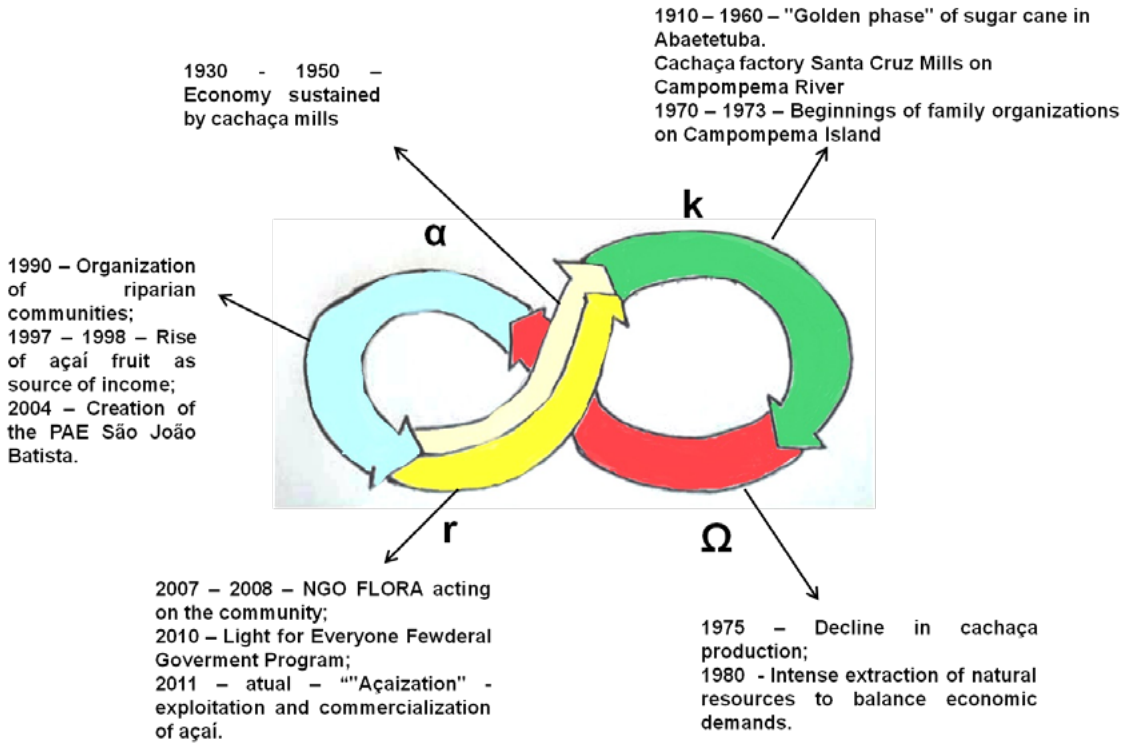

Figure 4 | Adaptive cycle with the historical trajectory of the PAE São João Batista, about the cultivation of sugar cane and açaí respectively. Phases: r – exploitation; k – conservation; Ω – release and α --re-organization.

Table 2 shows the evaluation of social, economic and natural capitals and their respective association with socioecological resilience.

Table 2 | *Evaluation of resilience in each phase of the adaptive cycle in the PAE São João Batista, Abaetetuba, Pará.*

Phases	*Social Capital*	*Economic Capital*	*Natural Capital*	*Value*	*Resilience*	*Land use*
Exploitation (r)	Strong 1	Strong 1	Strong 1	3	Resilient	Sugar cane
Conservation (k)	Weak 0	Strong 1	Weak 0	1	Slightly Resilient	Sugar cane
Release (Ω)	Weak 0	Weak 0	Weak 0	0	Non-Resilient	Sugar cane
Re-organization (α)	Strong 1	Strong 1	Strong 1	3	Resilient	Açaí
Exploitation (r)	Strong 1	Strong 1	Weak 0	2	Slightly Resilient	Açaí

Source: Elaborated by the authors.

Sugar cane cultivation in this riparian community in 1930, in the exploitation phase (r), structured a production system around the mill, with intensive labour, an abundance of natural resources and a high degree of commercialization. Although dealing with a monoculture, that phase was considered "Resilient". With that cultivation, its potential (the possibility of system transformation) increased together with the growth of interrelationships, following into phase k. The latter was characterized by the economic prosperity caused by sugar cane and the unleashing of disturbances resulting from labour laws, competition with other markets and participation of *ribeirinhos* in social movements, culminating in the organization of the community. The economical capital in phase k is positive, but social and environmental capitals were negative; hence, this phase was considered "Slightly Resilient."

Agents of change led to the collapse of the system (phase Ω), and the extraction of açaí palm hearts represented a reaction against sudden changes and created conditions for innovation. In this phase, all aspects are problematic, so it can be labelled "Non-Resilient".

The sugar cane cycle ends up reorganizing itself (phase α) taking advantage of opportunities such as the recognition and territorial demarcation of riparian communities like the PAE São João Batista, and the rise of açaí. *Ribeirinhos* showed an ability to organize themselves using plant extraction as a source of income, employment and social integration; therefore, it could be said that the phase of re-organization and current exploitation is "Resilient".

The cycle starts all over (phase r), now with an economic foundation in açaí management and social and economic capitals both considered strongly developed. However, the natural capital is weak, as that cultivation is a monoculture and has caused soil degradation, poor water quality and a threat to local biodiversity, thus characterizing a phase of "Slight Resilience".

On the other hand, the ribeirinhos are still dependent on a whole set of activities, such as the cultivation of medicinal species, particularly peppermint (*Mentha* sp.); catching fish and shrimp in rivers and streams, and handicraft making (Figure 5). This allows for new forms of adaptation and has led to a good level of resilience of the socioecological system, considering the number of changes they underwent. Furthermore, as the communities organized themselves into a form of settlement that attracted public policies and official support for production, we can acknowledge that settlement as "Resilient".

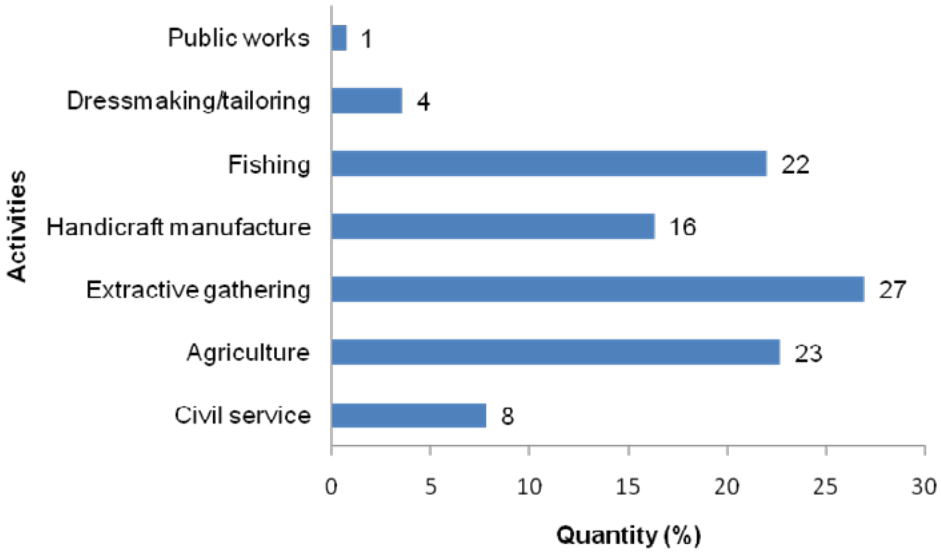

Figure 5 | Activities took by the riparian communities in the São João Batista settlement, Abaetetuba, Pará.

From a social standpoint, most of the community members remained in the settlement and adopted the extractive gathering of açaí fruit as their main activity, one that is expanding in the municipality and showed resilience to changes. Settlement policies, land reform and integration programs (such as *Bolsa Família*) indeed provided the necessary security in the period of disturbances in the SSE. Ecologically, although considered a low-impact activity, the exploitation of açaí changed to fulfil the increase in demand and, therefore, exerted pressure on floodplain forests and incurred an impact on biodiversity and the provision of ecosystem services.

The expansion of açaí planting to cram the floodplain forest areas where it already occurs naturally was regarded as a new way of development in the PAE São João Batista. Açaí is an important species for subsistence, for family income and to ensure land occupation, and signals the point of resilience in the community, which kept its structure and adopted the exploitation and commercialization of the fruit for self-organizing (phase α of the adaptive cycle). There was a potential for an unexpected and quick change that resulted in a process of positive feedback, maintaining its identity (BUSCHBACHER *et al.*, 2016). However, the environmental consequences of these changes have altered local biodiversity and landscape (GONÇALVES; BRASIL, 2016), due to the current extractive model practised by riparian communities in the Amazon estuary (FREITAS *et al.*, 2015).

3.3 "AÇAIZATION" AND THE FUTURE OF THE PAE

Increasing commercial demand for açaí fruit in Brazil and abroad made it the main source of income for the riparian communities in the Amazonian estuary. However, to survive in this ever-shifting market, agroextractivists intensified the management of açai in the varzea forests. Such practices in the estuarine floodplain involve thinning of sprouts and cutting of trees around the clumps of açaizais to allow more access to light and make the plant more competitive and transplanting seedlings from those clumps into areas of spontaneous occurrence of açaí to constitute homogenous formations of the plant (TAGORE, 2017). This type of management leaves the environment subjected to threats that could affect its ecological system, especially when açaí becomes the dominant species in the settlement (Figure 6), a fact referred to by Hiraoka (1993) as "açaization".

Figure 6 | Expressive presence of açaí (*Euterpe oleracea* Mart.) in the landscape of the PAE São João Batista, Campompema island, Abaetetuba, Pará.

Source: Elaborated by the authors.

The negative consequences of the intensive management of açaí in the PAE São João Batista have already begun to be perceived by the *ribeirinhos,* as statements such as the following often appeared in the interviews: *"The soil started to crumble because of felling the trees."* (N. C. N., 32 yo.). *"The land is lowering, tree roots are too much up there, so the tree loses its leaves, too much deforestation"* (A. S. S. N., 64 yo.); *"Açaí dries up in the tree because there is pollution, deforestation"* (R. S. N., 74 yo.); *"Açaí is hanging on up there, drying up, then it falls"* (J. M., 56 yo.); *"Animals are vanishing because they are killing the trees"* (M. S. A. F., 55 yo.).

In the 1990s, the production of native açaí fruit that was due almost exclusively to extractive gathering began to include also those taken from managed and cultivated native açaí trees (NOGUEIRA *et al*., 1995). The possibility of expanding the profitability of açaí production employing management by increasing palm densities in floodplains improved the income of families and kept the forest standing. Indeed, the goal of managing acai palm trees is to generate economic, ecological and social benefits to traditional communities (JARDIM, 2002): therefore, various techniques are employed to increase production and boost consumption and commerce (SANTOS JÚNIOR *et al*., 2015).

The expanding demand for açaí fruit has transformed a vast portion of the diverse riverine forest into a quasi-monodominant açaí forest and the changes were perceived by the *ribeirinhos* as they expressed in the interviews. Intensification of management and exploitation of açaí has resulted in the loss of over 50% of the diversity of tree species and a reduction of 63% in the number of pioneer species of the varzea forests (FREITAS *et al*., 2015). Removal of tree species from the floodplain often leads to poor yield and quality of açaí fruit, as the açaí palm tree is strongly dependent on ecosystem services such as pollination: according to Campbell *et al*. (2017), the presence of bees, in particular, is larger in floodplain areas surrounded by dense vegetative cover.

Still, on the suppression of the native vegetation, the interviews evidenced deforestation in river margins due to the extinction of the riparian forest, causing deposition of sediment in rivers. Gonçalves and Brasil (2016) and Tagore *et al*. (2018) also pointed at that environmental problem and emphasized that the fall of native trees weakens the cliff sides and river banks, and therefore the erosion and deposition of large amounts of sediments in the river beds.

The environmental threats to the estuary floodplains previously described were driven by a public policy based on the use of natural resources. Even if the ribeirinhos improved the infrastructure of their residences and boats with the implementation of the PAE with the financing that allowed the expansion of the açaí market, they faced new challenges with the preservation of the Amazonian estuary floodplain.

4 CONCLUSION

The history and the resilience of the community in the PAE São João Batista, Campompema island, Abaetetuba, Pará, are set in a given scale where the adaptive cycle reveals that the change (or disturbance) of the system occurred due to the decline in sugar cane yield. The transition of the economic system Sugar Cane-Açaí elicited the ability of the *ribeirinhos* to experiment with changes and created conditions for their re-organization as a settlement.

The phases of the adaptive cycle of exploitation and growth, anchored in the use and commercialization of açaí allowed by the settlement, classify the latter as “Resilient”. However, it is important to highlight the role of local institutions, public policies and the *ribeirinhos* in strengthening that resilience, as the challenge is to make them able to face periods of instability, taking advantage of the opportunities brought in by their productive activities such as fishing and the cultivation of other plant species, handicraft-making and cultural diversity.

In the current picture of increased pressure on floodplain forests for the production of açaí, collective actions must be worked on to better articulate their yield and commercialization and to create new socioecological relationships. That would ensure conservation and maintenance of environmental services in the floodplain forest, and the permanence and sustainability of riparian communities who live on the extractive gathering of açaí in their lands.

The adaptive cycle can be considered a heuristic model which, combined with resilience analysis, constitutes a useful tool to study the trajectory of socioecological systems in Amazonia and to identify possible determining factors of their changes and reorganizations. This would propitiate opportunities for planning in a context of quick and profound changes in the Anthropocene.

NOTES

[1] *This paper follows Lira* and Chaves (2016) and equally employs the words "riparian communities" and "ribeirinhos" to designate the residents of the PAE São João Batista, which is only accessible by inland waterway and whose way of life is identified by their use of forest and water resources.

[2] *Aviamento* was a system of credit focused on a commercial establishment that attached to the mill, where a primitive form of bookkeeping registered on a notebook the mill workers' withdrawals and their yield. At the end of the month, the withdrawals were discounted from the salary previously settled with the mill owner (MACHADO, 2008).

[3] *Bolsa Família* (Family Endowment) is a federal program of conditional transference of a stipend destined to poor families who meet certain conditions related to health and education (SILVA; PAES, 2019).

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Trajetória histórica e resiliência em um projeto de assentamento agroextrativista no Baixo Rio Tocantins, Pará, Brasil

Historical trajectory and resilience in an agro-extractive settlement project in the Lower Tocantins River, Pará, Brazil

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doi:10.18472/SustDeb.v12n2.2021.34091

Received: 14/09/2020
Accepted: 06/07/2021

ARTICLE – VARIA

RESUMO

A comunidade ribeirinha São João Batista vivenciou uma fase áurea da produção da cachaça de cana-de-açúcar (*Saccharum officinarum* L.). Tendo passado por um período de decadência por volta de 1975, veio a se tornar um Projeto de Assentamento Agroextrativista (PAE) em 2004, agora com seu sistema econômico baseado na exploração e comercialização do açaí (*Euterpe oleracea* Mart.). Este estudo analisa a resiliência da comunidade do PAE São João Batista, Abaetetuba, Pará, em função do estabelecimento de engenhos de cana-de-açúcar e a transição do sistema econômico para a exploração e comercialização do açaí. O estudo se baseou em pesquisa de campo com 141 ribeirinhos por meio de entrevistas semiestruturadas. Construiu-se o ciclo adaptativo, a partir do qual foi feita a análise de resiliência. O crescimento do mercado do fruto de açaí assinalou o ponto de resiliência da comunidade. A transição cana-açaí efetivou a capacidade dos ribeirinhos de experimentar mudanças e criar condições para se reorganizarem enquanto assentamento.

Palavras-chave: Adaptação. Usos da biodiversidade. Sistema Socioecológico. Abaetetuba.

ABSTRACT

The São João Batista riverside community experienced a golden phase in the production of cachaça from sugar cane (Saccharum officinarum L.). It underwent a period of decay around 1975 and, in 2004, became an Agroextractive Settlement Project (PAE), with an economic system based on the exploitation and commercialization of açaí (Euterpe oleracea Mart.). This study analyzes the resilience of PAE São

João Batista, Abaetetuba, Pará, from the establishment of sugar cane mills to the transition of their economic system to the exploitation and commercialization of açaí. It was based on field research conducted with 141 riverside dwellers by means of semi-structured interviews. The adaptive cycle was built up, from which resilience was analyzed. The growth of the açaí fruit market identifies the community's point of resilience. The sugar cane-açaí economic system transition enabled riparian populations to experience changes and to create conditions for reorganizing themselves as a settlement.

Keywords: Adaptation. Uses of biodiversity. Socioecological System. Abaetetuba.

1 INTRODUÇÃO

As paisagens socioecológicas amazônicas foram moldadas pela ação humana em diferentes intensidades, e o uso e aproveitamento de seus recursos naturais levam a um palco de lutas e conflitos estabelecidos entre diversos atores e interesses (ATHAYDE *et al*., 2016). Entre esses atores estão as populações tradicionais, que socialmente reproduzem seus modos de vida em interação com o ambiente.

Nas várzeas do estuário do Amazonas, as populações ribeirinhas estabeleceram sistemas de uso dos recursos naturais caracterizados pela combinação de várias atividades de subsistência, com base na mão de obra familiar e uso de tecnologias de baixo impacto, derivadas de conhecimentos tradicionais (FERREIRA, 2012; LIMA; POZZOBON, 2005). A preocupação com o reconhecimento dos direitos territoriais das populações tradicionais e da sustentabilidade dos territórios e dos sistemas produtivos conduziu à criação dos territórios rurais de identidade agroextrativista, culminando com a criação dos Projetos de Assentamento Agroextrativista (PAE) como uma unidade de conservação de uso sustentável, conforme as demandas do movimento ambientalista e as reivindicações fundiárias dos movimentos sociais (ARAÚJO *et al*., 2019).

Para entender como as comunidades são afetadas e respondem a perturbações, a teoria de sistemas complexos vem sendo aplicada sob a ótica da representação de sistemas socioecológicos (SSE). No Rio Tocantins, na grande área afetada pela Barragem de Tucuruí, Bentes *et al*. (2014) mostraram que algumas comunidades vêm se organizando por meio de acordos de pesca, em busca de melhores condições de vida. Isso evidencia que as transformações, associadas direta ou indiretamente à destruição de hábitat, mudanças climáticas e superexploração da biodiversidade (SILVA *et al*., 2020), vêm atingindo os grupos humanos que mais dependem dos recursos naturais por causa de seus efeitos nos sistemas socioecológicos (HE; SILLIMAN, 2019).

Os PAEs podem ser vistos como um modelo de SSE onde o sistema social compreende os agricultores, extrativistas, pescadores, suas formas de produção, suas instituições, as cadeias produtivas, as relações e processos sociais. O sistema ecológico é abordado em diferentes escalas, que vão desde os diversos ambientes terrestres e aquáticos até a unidade das espécies extraídas nesses assentamentos. Os sistemas social e ecológico interagem resultando no "sistema agroextrativista", que está incluído em sistemas socioecológicos em escala ampla, como o mercado internacional (do açaí, por exemplo), os biomas, o clima global, etc. (OSTROM, 2009).

Sob essa perspectiva, emerge a abordagem da resiliência, cuja interface sociedade-natureza é vista a partir das relações de retroalimentação que caracterizam o SSE (LINDOSO, 2017). A resiliência de um sistema é definida como a capacidade de um sistema de lidar com perturbações enquanto mantém suas funções (FOLKER *et al*., 2004). No contexto amazônico, Buschbacher (2014) usa o termo resiliência como "a capacidade de lidar com incertezas, mudanças e surpresas por meio de adaptação, aprendizagem e auto-organização". Por meio do ciclo adaptativo (HOLLING; GUNDERSON, 2002), é possível descrever como ocorrem os padrões e os processos de mudança ao longo do tempo nos sistemas.

Nessa dinâmica, o resgate histórico do acesso à terra e as estratégias de sobrevivência dos ribeirinhos diante dos efeitos de eventos ambientais e suas consequências, bem como as formas de adaptação ao mercado capitalista, possibilitam uma análise sobre a resiliência socioecológica e as possibilidades de planejamento a longo prazo. Em particular, para as populações tradicionais amazônicas, a capacidade dos sistemas socioambientais de responder e se ajustar ao seu meio evidencia seu papel na conservação da floresta amazônica sob a perspectiva das mudanças ambientais globais, tendo o poder de agenciamento de transformações políticas em diversas escalas e territórios (FLEURY et al., 2019).

Nesse sentido, este trabalho apresenta uma análise da trajetória e resiliência do PAE São João Batista, no município de Abaetetuba (Pará), utilizando elementos das abordagens de sistemas socioecológicos e resiliência (HOLLING, 2001; WALKER *et al*., 2006). Considerando o ciclo adaptativo como um modelo heurístico, essa ferramenta foi utilizada para explorar as dinâmicas e trajetórias de mudança do SSE a partir do estabelecimento de engenhos de cana-de-açúcar em 1930 e a transição do sistema econômico para a exploração e comercialização do açaí. As tendências de resiliência foram analisadas à luz das dimensões dos capitais social, econômico e ambiental (SALVIA; QUARANTA, 2015), considerando as diferentes fases do ciclo adaptativo.

2 MATERIAL E MÉTODOS

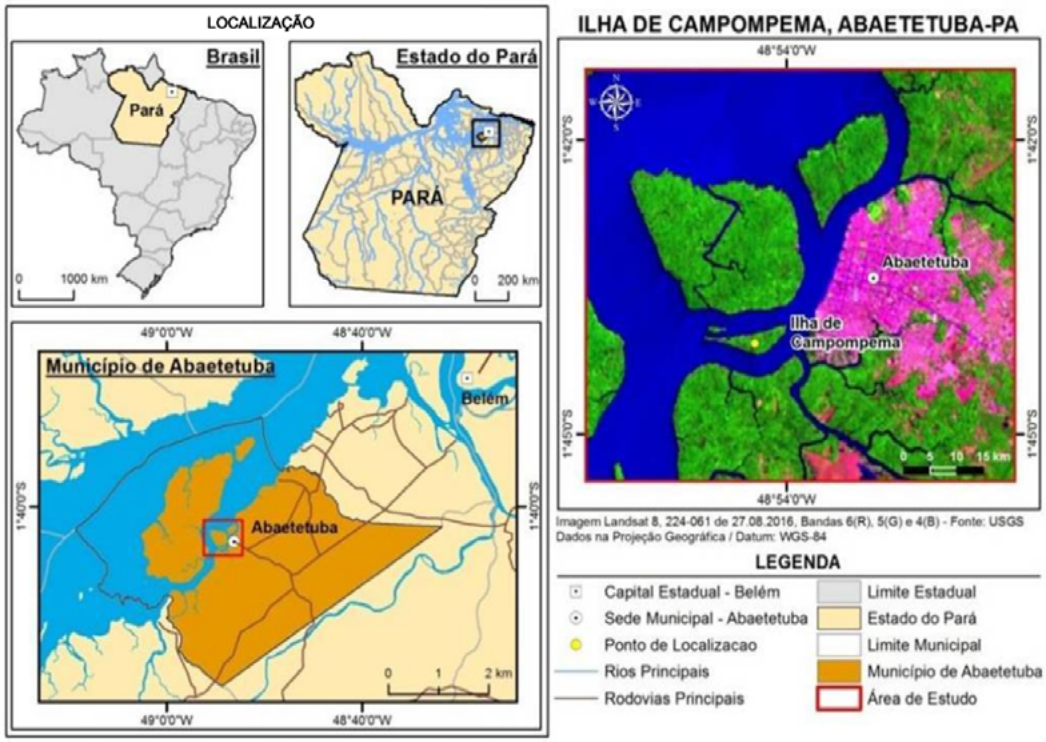
2.1 ÁREA DE ESTUDO

O município de Abaetetuba (01º43’24”S, 48º52’54”W) tem uma população de 141.100 habitantes (IBGE, 2010) e sua economia está baseada, principalmente, nas atividades de pesca, do extrativismo – sobretudo do açaí – e na agricultura (BARROS, 2009). Juntamente com outros dez municípios, compõe a região do Baixo Tocantins, e sua história está associada ao processo de colonização da Amazônia, caracterizado por um modelo de integração econômica ao capitalismo internacional (MACHADO, 2008).

Do ponto de vista socioambiental, Abaetetuba tem uma expressiva diversidade marcada por saberes, memórias, fazeres, simbologias, costumes e uma rotina entrelaçada com os espaços dos rios, das matas e áreas de várzea (POJO; ELIAS, 2018). Conta com 72 ilhas que estão geograficamente situadas no baixo curso do Rio Tocantins, já na confluência com o Rio Pará, no estuário paraense, em uma região constituída predominantemente de áreas de várzea e habitadas por comunidades ribeirinhas e quilombolas que mantêm ligação com a cidade em maior ou menor intensidade, consoante a distância ao centro urbano (BARROS; SILVA, 2013).

Para este estudo, foi escolhida a Ilha de Campompema (Figura 1), onde se situa o PAE São João Batista. Justifica-se a seleção dessa área por se tratar de uma das primeiras localidades de implantação do Projeto de Assentamento Agroextrativista (PAE) na Amazônia, integrando o conjunto de modelos de projetos de reconhecimento fundiário criados no ano de 2004 como forma de dinamizar as ações econômicas e ambientais nas áreas de várzea historicamente ocupadas por populações tradicionais.

Figura 1 | Localização da área de estudo.



Fonte: Elaborado pelos autores.

O PAE São João Batista foi criado por meio da Portaria INCRA/SR (01)/Nº 27 de 27 de julho de 2004, publicada no Diário Oficial da União Nº 146 de 30/07/2004, Seção I, compreendendo uma área de 471.9661ha (INCRA, 2017). Esse assentamento é resultado das lutas dos movimentos sociais locais para conseguir a regularização fundiária. Inicialmente, os ribeirinhos receberam o Termo de Autorização de Uso Sustentável emitido pela Secretaria de Patrimônio da União, sendo esse documento um elemento facilitador para o acesso aos benefícios sociais do governo e eficaz para comprovar a residência (IPEA, 2015).

Os ribeirinhos do PAE São João Batista desenvolveram estratégias de sobrevivência baseadas no uso dos recursos naturais, tanto relacionadas à pesca como ao extrativismo de produtos florestais, para se adaptarem às mudanças de ordem política, social, ambiental e econômica. O assentamento São João Batista vivenciou a fase áurea da produção da cachaça de cana-de-açúcar (*Saccharum officinarum* L.) na década de 1960; teve posteriormente seu momento de decadência 15 anos depois, e em 2019, enquanto assentamento rural, passa a usufruir de um sistema econômico baseado principalmente na exploração e comercialização do fruto de açaí (*Euterpe oleracea* Mart.), que tem mercado global.

2.2 COLETA DE DADOS

Para a realização da pesquisa, de caráter analítico-descritivo, inicialmente foram realizadas reuniões com a liderança comunitária para exposição da natureza do trabalho e autorização da pesquisa por meio do Termo de Consentimento Livre e Esclarecido (TCLE). Posteriormente, os documentos resultantes desse momento prévio foram encaminhados à Plataforma Brasil para avaliação. O Comitê de Ética

em Pesquisa do Instituto de Ciências da Saúde da Universidade Federal do Pará (UFPA) aprovou sua execução sob o CAAE 74844417.4.0000.0018.

O estudo incluiu pesquisa de campo realizada no período de março a agosto de 2018 no PAE São João Batista. Os sujeitos envolvidos na pesquisa foram os moradores da área do assentamento, totalizando 141 entrevistados (49% da população residente no PAE). A idade dos entrevistados variou de 18 a 59 anos, com uma porcentagem maior (67%) de mulheres.

A coleta de dados, por meio de entrevistas semiestruturadas, visou conhecer o modo de vida da população e identificar os eventos históricos e os principais fatores que influenciaram a trajetória de implantação do assentamento. As entrevistas foram realizadas de 7h às 17h, conduzidas nas residências dos entrevistados, com a realização de no máximo três entrevistas por dia.

Devido à situação fundiária das ocupações, e o acesso aos recursos naturais na Comunidade São João Batista estar sujeito a normas estabelecidas pelas comunidades do Projeto de Assentamento Agroextrativista, os questionamentos poderiam gerar desconforto por receio de perdas financeiras e/ou materiais. Nesse caso, foi garantida a interrupção da entrevista, conforme a autonomia e livre vontade do entrevistado.

Os relatos dos entrevistados se encontram referenciados ao longo do texto com as letras iniciais do nome e a idade, garantindo-lhes o sigilo de sua identidade. Posteriormente, foi realizada pesquisa na literatura científica (artigos, livros e sítios institucionais) para verificar as intervenções políticas no assentamento, além de registros históricos.

2.3 CONSTRUÇÃO DO CICLO ADAPTATIVO

Holling (2001) propõe um modelo de ciclo adaptativo de quatro fases, onde um sistema cresce lentamente (fase de exploração), acumula riqueza por um período sustentado de tempo (fase de conservação), colapsa (fase de liberação) e rapidamente se reorganiza (fase de reorganização), permitindo crescer em uma configuração idêntica ou diferente (HOLLING; GUNDERSON, 2002).

A identificação das quatro fases do ciclo adaptativo: r – exploração; k – conservação; Ω – liberação e α – reorganização foi realizada com base nas entrevistas e consulta à literatura, percorrendo os ciclos adaptativos da cana-de-açúcar e no do açaí, de 1930 até 2018. Assim, seria possível abranger a reconstrução da memória histórica dos atores locais, mesmo porque esse período assinalava a transição da agricultura da cana para o manejo de uma das espécies mais importantes do extrativismo amazônico, que participa do mercado global.

Para a descrição das fases do ciclo adaptativo, consideraram-se os pressupostos detalhados na Tabela 1, com atribuição de valores referentes aos capitais social, econômico e natural, sendo 1 (um) para os critérios considerados fortes e 0 (zero) para os considerados fracos, conforme Salvia e Quaranta (2015). O capital forte garante um alto nível de potencial de resiliência, assim como, inversamente, o capital fraco sinaliza uma incapacidade do SSE de adaptação, transformação e resposta geral às mudanças, influenciando assim o grau de resiliência do sistema. Os critérios foram identificados

combinando os componentes que indicariam se o capital econômico, social e natural estariam bem ou mal desenvolvidos no assentamento.

Tabela 1 | Critérios para caracterizar a resiliência das fases do ciclo adaptativo em função dos cultivos de cana-de-açúcar e açaí no PAE São João Batista, Abaetetuba, Pará.

Fases (Anos)	*Capital*			*Descrição*
	Social	*Econômico*	*Natural*	
Exploração (r) 1930 - 1950	Presença da comunidade unida; alta diversidade (1)	Ribeirinhos têm abundância de recursos; alta comercialização (1)	Prática de plantio sem agressão à biodiversidade local; espécies, como o açaí, manejados para sobrevivência (1)	Capital socioeconômico e ambiental fortemente desenvolvido (1)
	Ausência de comunidade unida; baixa diversidade (0)	Ribeirinhos não têm abundância de recursos; alta dependência de financiamento externo; baixa comercialização (0)	Monocultura; simplificação da paisagem; degradação do solo (0)	Capital socioeconômico e ambiental pouco desenvolvido (0)
Conservação (k) 1960 - 1973	Boa comunicação entre os atores sociais; investimento em infraestrutura e instituições para educação de crianças e jovens (1)	Alta produtividade; escoamento da produção; geração de emprego e renda para a família (1)	Baixa degradação da floresta e do solo; preservação dos recursos hídricos (1)	Capital socioeconômico e ambiental fortemente desenvolvido (1)
	Ausência de comunicação entre os atores sociais; investimento em infraestrutura e instituições para educação de crianças e jovens (0)	Baixa comercialização dos recursos; dificuldades no escoamento da produção; na geração de emprego e renda (0)	Alta degradação da floresta e do solo; recursos hídricos esgotados (0)	Capital socioeconômico e ambiental pouco desenvolvido (0)
Liberação (Ω) 1975 - 1987	Alta diversidade; incorporação de técnicas tradicionais de cultivo; apoio a programas sociais da comunidade (1)	Alta comercialização dos produtos (1)	Baixa exploração do açaí (1)	Capital socioeconômico e ambiental fortemente desenvolvido (1)
	Baixa diversidade; precariedade tecnológica; falta de apoio a programas sociais da comunidade; situação precária de trabalho; informalidade da ocupação (0)	Baixa comercialização dos produtos (0)	Acentuado processo de exploração do açaí (0)	Capital socioeconômico e ambiental pouco desenvolvido (0)

Fases (Anos)	Capital			Descrição
	Social	Econômico	Natural	
Reorganização (α) 1990 - 2004	Capacidade de organização em redes e instituições de base como cooperativas, associações; presença de serviços de consultoria para os ribeirinhos (1)	Baixa necessidade de importar recursos para sobreviver na comunidade; extrativismo vegetal como fonte de renda e garantia de empregos (1)	Recursos naturais disponíveis para exploração; boa qualidade da água e do solo (1)	Capital socioeconômico e ambiental fortemente desenvolvido (1)
	Ausência de organização em redes e instituições de base como cooperativas, associações; presença de serviços de consultoria para os ribeirinhos (0)	Alta necessidade de importar recursos para sobreviver na comunidade (0)	Ausência de recursos naturais disponíveis para exploração; boa qualidade da água e do solo (0)	Capital socioeconômico e ambiental pouco desenvolvido (0)
Exploração (r) 2007 - atual	Mobilização social; presença de escolas e serviços aos ribeirinhos; inclusão social das famílias (1)	Alta comercialização dos recursos; participação em programas de apoio financeiro; aceitação no mercado (1)	Boa qualidade do solo, da água; preservação da biodiversidade local (1)	Capital socioeconômico e ambiental fortemente desenvolvido (1)
	Ausência de organização social; faltam escolas e serviços aos ribeirinhos (0)	Baixa comercialização dos recursos; ausência de participação em programas de apoio financeiro; falta de aceitação no mercado (0)	Monocultura; Degradação do solo, má qualidade da água; biodiversidade local ameaçada (0)	Capital socioeconômico e ambiental pouco desenvolvido (0)

Fonte: Elaborado pelos autores.

As mudanças no PAE foram analisadas à luz da dinâmica que moldou os capitais social, econômico e natural descritos na Tabela 1. A análise das tendências de resiliência, extrapoladas a partir das trajetórias dos três diferentes tipos de capitais, levou à construção do ciclo adaptativo de 1930 a 2018 para os setores de cultivo da cana-de-açúcar e de produção de açaí. Partindo dos critérios apresentados na Tabela 1 e, posteriormente, com base nos níveis atribuídos ao capital (forte ou fraco), obtiveram-se a valoração e indicação da resiliência em cada fase do ciclo adaptativo, como Não Resiliente = 0; Pouco Resiliente = 1-2 e Resiliente = 3. Os indicadores de resiliência incorporam as diferentes fases do ciclo adaptativo e podem atuar como um barômetro da resiliência geral, pois sua presença sugere um SSE resiliente, enquanto sua ausência ou desaparecimento sugere uma perda de resiliência e maior vulnerabilidade a distúrbios (CABELL; OELOFSE, 2012). O fluxograma da pesquisa com suas etapas é apresentado na Figura 2.

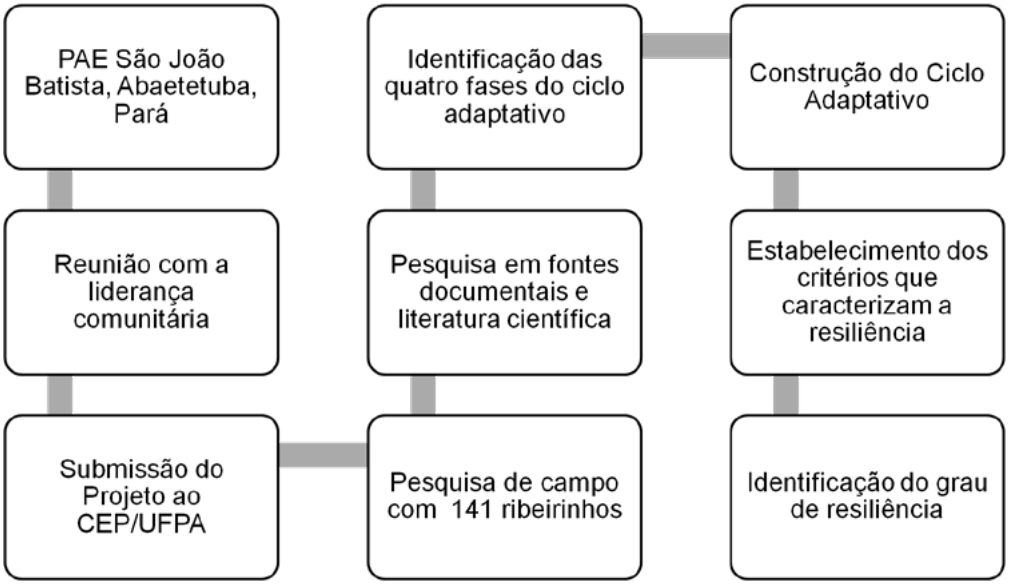


Figura 2 | Fluxograma da Pesquisa no PAE São João Batista, Abaetetuba, Pará.

3 RESULTADOS E DISCUSSÃO

Ao longo de trajetória histórica (Figura 3) a cana e o açaí foram recursos necessários à reprodução socioeconômica dos ribeirinhos do PAE São João Batista, pois por intermédio deles ocorreu o processo de ocupação do território e exploração dos recursos naturais e mudanças de usos da terra.

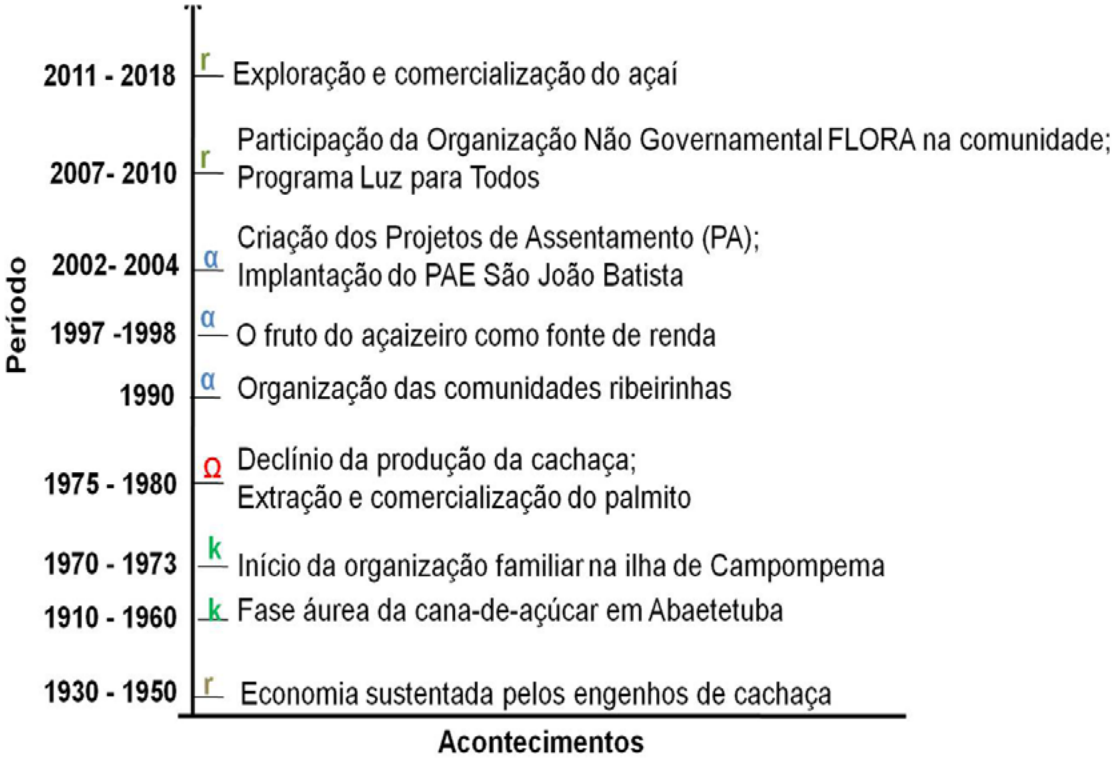


Figura 3 | Trajetória histórica do território do PAE São João Batista com base nos cultivos de cana e açaí.

3.1 FASES DO CICLO ADAPTATIVO DO PAE SÃO JOÃO BATISTA

3.1.1 CANA-DE-AÇÚCAR – EXPLORAÇÃO (r)

Em 1930, os ribeirinhos da Ilha de Campompema trabalhavam no engenho Santa Cruz, do sr. Murilo Parente Carvalho, localizado no Rio Abaeté, que ficou em funcionamento até por volta dos anos 1960, e orientava a vida econômica, social e ambiental dos moradores, conforme a descrição a seguir: "*Aqui na comunidade tinha o Engenho Santa Cruz e produzia muita cachaça, e o ganho sustentava nossa vida aqui na comunidade*" (B.L.S., 83 anos). "*Não tinha venda de açaí, vendia cachaça"* (R.N., 74 anos).

A cana era cortada em pedaços de aproximadamente 80 cm de comprimento e amontoada no campo em feixes, que eram carregados e amontoados em lotes de dez, formando uma frasqueira (unidade de medida para fins de transação comercial entre o canavialista e o engenheiro) de cana (ANDERSON, 1991). Em muitos casos, acontecia a meação no plantio de cana, entrando o senhor de engenho com as terras e o lavrador com o seu trabalho (NAHUM, 2011).

O canavialista (agricultor que plantava a cana) obtinha financiamento para as despesas (preparo, manutenção e corte de um roçado de cana) com o dono do engenho (engenheiro). Em troca do aviamento[2] – feito com produtos de consumo postos à disposição no comércio do engenho – de um roçado de cana, o engenheiro esperava do canavialista a entrega de toda a sua produção. Era uma relação pessoal e informal que beneficiava apenas um décimo dos agricultores, ficando aqueles sem recursos próprios ou aviamento relegados a trabalharem como diaristas (ANDERSON, 1991).

3.1.2 CANA-DE-AÇÚCAR – CONSERVAÇÃO (K)

O engenho Santa Cruz, juntamente com outros engenhos familiares, assegurava à população da área de várzea uma renda estável (ROGEZ, 2000), especialmente na década de 1960, quando a produção canavieira atingiu sua fase áurea em Abaetetuba. Em razão do aumento da demanda, ocorreu a instalação das primeiras máquinas a vapor destinadas à produção exclusiva da aguardente, cuja qualidade fez fama em todo o estado do Pará (MACHADO, 2008). Porém, os engenhos funcionaram sempre de acordo com uma concepção primitiva de produção e de relação econômica, e com o passar do tempo essa forma de sobrevivência foi entrando em decadência.

Nos anos 1970, muitos trabalhadores recorreram ao sistema judiciário para reclamarem seus direitos perante aos patrões dos engenhos, e a fim de evitar um conflito social de maiores proporções, o regime estatal determinou que os proprietários distribuíssem partes de suas terras em forma de loteamento para sanar as indenizações trabalhistas (QUARESMA *et al*., 2015).

3.1.3 CANA-DE-AÇÚCAR – LIBERAÇÃO (Ω)

O plantio e a comercialização da cana começaram a declinar em 1975, pois *"O trabalho era escravo, ganhava três mil réis por semana, aí veio a justiça do trabalho e acabou com o engenho*" (R.N., 74 anos). Para alguns ribeirinhos, "*a vida no engenho era cansativa, só o dono tinha lucro*" (J.M., 56 anos). De fato, nos engenhos predominava o trabalho intensivo, e quando a produção da cachaça começou a passar por crises, os trabalhadores não recebiam incentivos do governo e acabavam sendo os mais afetados (QUARESMA *et al*., 2015). Além disso, a situação precária dos engenhos, a recusa à substituição do sistema de aviamento por relações mais modernas, a precariedade tecnológica e a inclusão de novas normas trabalhistas contribuíram para a decadência (MACHADO, 2008; NAHUM, 2011).

Com a redução das atividades nos engenhos, "*cada um começou a cuidar do seu sítio*" (J.M., 56 anos), e diante de uma situação de inconformismo de alguns ribeirinhos insatisfeitos com a situação e que desejavam melhorias, entre 1970 e 1973 começaram a ocorrer encontros com representantes da Igreja Católica para discutir a organização familiar na Ilha de Campompema. "*Quatro moradores tiveram ajuda da diocese para criar a comunidade, foi então que organizaram as famílias para ter registro e ser reconhecido*" (B.L.S., 83 anos), culminando na criação da Comunidade São João Batista. O papel da Igreja foi fundamental nesse processo de territorialização das comunidades ribeirinhas, uma vez que desenvolveu construções políticas nos campos teórico e prático visando despertar a consciência para as reais situações desencadeadoras de opressão (GONÇALVES; RODRIGUES; SOBREIRO FILHO, 2019).

A criação da comunidade coincidiu com o período de decadência da produção canavieira, período em que o desaquecimento da produção de aguardente levou o sistema ao colapso, e os trabalhadores que viviam dessa atividade decadente passaram a procurar por outras formas de sobrevivência, pois *"Não existia nada, a situação era de abandono"* (J.M., 56 anos). Os recursos tradicionais de alimentação foram explorados com intensidade cada vez maior: a caça foi praticamente extinta; a pesca passou a render pouco; o camarão, em vez de complementar a dieta familiar, era capturado predatoriamente para revenda; e açaizais inteiros foram derrubados para vender o palmito às fábricas localizadas no estuário (ANDERSON, 1991).

A destruição de açaizeiros foi tão intensa a ponto de ser necessária uma intervenção estatal por meio da Lei n° 6.576/1978, proibindo o abate da palmeira açaí em todo o território nacional – o que parece não ter tido muito efeito, pois, em 1980, o Pará se tornou a principal unidade da Federação na extração e produção do palmito em conserva (MOURÃO, 2010).

3.1.4 REORGANIZAÇÃO (α)

A intensa exploração dos açaizeiros se associava à informalidade da ocupação, pois a dominialidade territorial era federal e isso permitia que as comunidades ribeirinhas se tornassem vulneráveis à atuação de terceiros (ALVES, 2016). Entretanto, a partir de 1990, a Comissão Pastoral da Terra (CPT), as Comunidades Eclesiais de Base (CEBs), os Sindicatos de Trabalhadores e Trabalhadoras Rurais (STTRs), a Colônia de Pescadores e as associações locais se mobilizaram buscando a organização das comunidades ribeirinhas para reconhecimento, demarcação e titulação territorial (GONÇALVES *et al*., 2016).

Concomitante a esse processo de organização, o padrão produtivo do açaí foi sendo alterado, de extrativo para manejo cultivado e/ou direcionado (FERREIRA, 2012). O crescimento do mercado do fruto do açaí a partir da década de 1990 provocou um efeito positivo na sua preservação e conservação (TAVARES; HOMMA, 2015). Esse fruto, entre os anos de 1997 e 1998, foi uma importante fonte de renda, sobretudo em função da crescente procura no comércio externo a essa região, o que favoreceu a implementação, em 2002, dos Projetos de Assentamento (PAs) na região das Ilhas de Abaetetuba (FERREIRA, 2012; GONÇALVES *et al*., 2016).

Nas várzeas amazônicas, o expoente mais significativo no período 2002-2004 foi o Projeto de Assentamento Agroextrativista (PAE), que prevê a exploração de áreas dotadas de riquezas extrativas por meio de atividades economicamente viáveis, socialmente justas e ecologicamente sustentáveis, a serem executadas pelas populações que ocupem ou venham ocupar as mencionadas áreas (BRASIL, 1996). Na Ilha de Campompema, o PAE São João Batista foi implementado em 2004, tendo como uma de suas finalidades a de fomentar a cadeia produtiva dos recursos naturais explorados (ALVES, 2016).

3.1.5 AÇAÍ – EXPLORAÇÃO (r)

A utilização do açaí durante a exploração e comercialização da aguardente de cana-de-açúcar era direcionada para a sobrevivência familiar, compreendendo a coleta do fruto e corte de cipós para facilitar a colheita manual do fruto, com poucas alterações atribuídas à ação humana, visto que a abundância natural das palmeiras garantia a quantidade que atendesse às necessidades domésticas, e o manejo restringia-se basicamente às touceiras dos quintais, onde os frutos eram coletados (MARINHO, 2009).

Essa dinâmica, no entanto, começou a mudar com a progressiva demanda do açaí para o mercado, favorecendo na Ilha de Campompema a implementação do PAE São João Batista, o que gerou desenvolvimento socioeconômico e ambiental para a comunidade. Segundo relatos dos moradores, em 2007 e 2008 a Organização Não Governamental Flora atuou na comunidade por meio da criação de um módulo de plantio permanente de açaizeiros para os ribeirinhos, objetivando reforçar a conservação da floresta. Em 2010, a Ilha de Campompema foi inserida no Programa Luz para Todos (LPT), criado pelo governo federal, política pública federal implementada por meio do Decreto n° 4.873, de 2003, para promover a inclusão social das famílias rurais de baixa renda mediante o fornecimento dos serviços de distribuição de energia (FREITAS; SILVEIRA, 2015).

O LPT trouxe geração de energia a 41 residências (entre os entrevistados) que conseguiram se cadastrar no PAE São João Batista; e as famílias que não conseguiram efetuar o cadastro residem com energia disponibilizada pelas Centrais Elétricas do Pará (Celpa) nos padrões normais de abastecimento. Há ainda redes instaladas pelos próprios usuários, totalizando 100 famílias que desfrutam de energia elétrica.

No assentamento, há ainda a atuação de instituições, como o Movimento dos Ribeirinhos e Ribeirinhas das Várzeas de Abaetetuba (Moriva), o Movimento dos Ribeirinhos e Ribeirinhas dos Projetos de Assentamento (Moripa), as Igrejas, a Associação do PAE São João Batista e, mais recentemente a Prefeitura de Abaetetuba, a qual implementou um sistema de abastecimento e distribuição de água aos ribeirinhos, que tem favorecido a exploração e a comercialização do fruto do açaí, passando a atender aos mercados internos e externos. Estima-se que seja a principal fonte de receita para 77% da população rural do nordeste do estado do Pará (SANTANA *et al*., 2012).

Nesse cenário, os ribeirinhos do assentamento São João encontraram no açaí o componente básico da geração de renda, o que justifica a apropriação que fazem da área de várzea para manejo dessa palmeira, identificada em 75% dos estabelecimentos familiares analisados. O manejo da floresta de várzea para produção do açaí é realizado nos meses de entressafra (janeiro a julho) e envolve a derrubada dos açaizeiros mais elevados e pouco produtivos, a limpeza do terreno e o enriquecimento (plantação de novas palmeiras de açaí). Nesse período de entressafra, a fonte de renda é a venda de artesanato, peixes e camarão na feira local e ainda as transferências financeiras feitas pelo governo como o Bolsa Família[3].

A comercialização dos frutos ocorre na feira local ou por meio da Cooperativa dos Fruticultores de Abaetetuba (Cofruta), criada em março de 2002, em que participam oito ribeirinhos do assentamento (Informante da pesquisa). Além da Cofruta, os ribeirinhos, por meio do agroextrativismo do açaí, buscaram fomentar sua cadeia de produção mediante acesso ao microcrédito e consultoria empresarial, com isso 13% dos ribeirinhos solicitaram apoio do programa Amazônia Florescer, do Banco da Amazônia, para que uma família possa ter recursos para potencializar o desenvolvimento de suas atividades extrativistas. Como exemplo, 7% das famílias estavam consolidando parceria com a empresa “100% Amazônia” para vender açaí por melhor preço.

3.2 CICLO ADAPTATIVO E RESILIÊNCIA DO PAE SÃO JOÃO BATISTA

Quanto a suas condições sociais, econômicas e ambientais, nota-se que existe um processo histórico de ocupação no PAE associado aos modos de vida da população em interação com o meio ambiente de várzea e a produção de cana e açaí. Diante de sua importância, a trajetória histórica foi ilustrada no ciclo adaptativo em função desses cultivos (Figura 4).

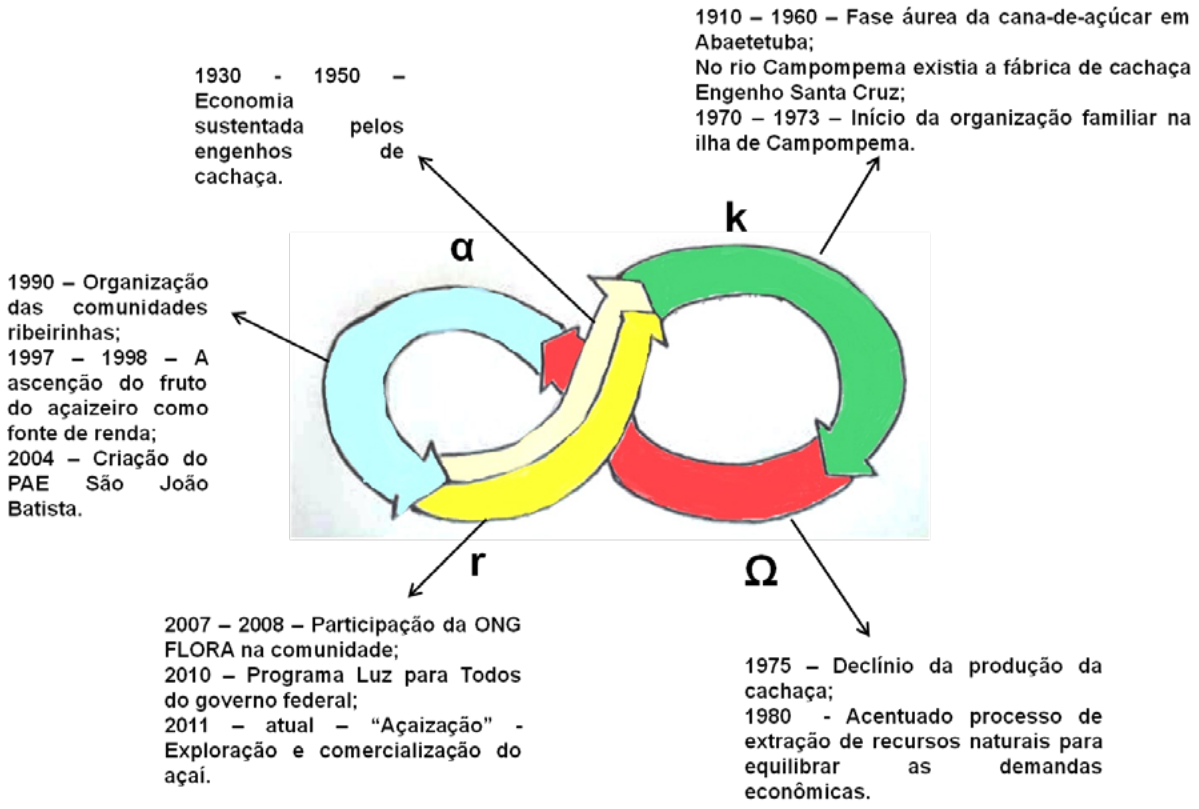


Figura 4 | Ciclo adaptativo com a trajetória histórica do PAE São João Batista, em função dos cultivos de cana-de-açúcar e de açaí. Legenda: r – exploração; k – conservação; Ω – liberação e α – reorganização.

Fonte: Elaborado pelos autores.

A Tabela 2 mostra a avaliação dos capitais social, econômico e natural e sua associação com a resiliência socioecológica.

Tabela 2 | Avaliação da resiliência em cada fase do ciclo adaptativo no PAE São João Batista, Abaetetuba, Pará.

Fases	*Capital Social*	*Capital Econômico*	*Capital Natural*	*Valor*	*Resiliência*	*Usos da terra*
Exploração (r)	Forte 1	Forte 1	Forte 1	3	Resiliente	Cana
Conservação (k)	Fraco 0	Forte 1	Fraco 0	1	Pouco Resiliente	Cana
Liberação (Ω)	Fraco 0	Fraco 0	Fraco 0	0	Não Resiliente	Cana
Reorganização (α)	Forte 1	Forte 1	Forte 1	3	Resiliente	Açaí
Exploração (r)	Forte 1	Forte 1	Fraco 0	2	Pouco Resiliente	Açaí

Fonte: Elaborado pelos autores.

O cultivo da cana-de-açúcar em 1930, na fase caracterizada como de exploração (r) da comunidade ribeirinha, estruturou um sistema de produção em torno do engenho, com utilização de mão de obra intensiva, abundância do recurso natural e alta comercialização. Embora em função de uma monocultura, essa fase foi considerada "Resiliente".

Com o cultivo da cana, o potencial (possibilidade de transformação do sistema) aumentou juntamente com o crescimento das inter-relações, seguindo para a fase k. Esta foi marcada pela prosperidade econômica que a cana ocasionou e pelo desencadeamento de perturbações resultantes das leis trabalhistas, concorrência com o mercado de outras regiões e inserção de ribeirinhos em movimentos sociais, culminando na organização da comunidade. O capital econômico na fase k é positivo, mas os capitais social e ambiental são negativos: logo essa fase foi "Pouco Resiliente".

Os agentes de mudança geraram o colapso do sistema (fase Ω), utilizando a extração do palmito como resposta às mudanças abruptas e criando condições para o aparecimento de inovações. Nessa fase, todos os aspectos estão com problemas, indicando a "Não Resiliência".

O ciclo da cana finaliza reorganizando-se (fase α) mediante oportunidades, entre elas o reconhecimento e a demarcação territorial das comunidades ribeirinhas, como o PAE São João Batista, e a ascensão do açaí. Os ribeirinhos apresentaram capacidade de organização utilizando o extrativismo vegetal como fonte de renda, emprego e inclusão social, consequentemente, pode-se ponderar que a fase de reorganização e exploração (atual) tem "Resiliência".

O ciclo reinicia (fase r), agora com a base econômica no manejo do açaí e os capitais social e econômico considerados fortemente desenvolvidos. Entretanto, o capital natural é fraco, pois esse cultivo, além de ser uma monocultura, tem ocasionado degradação do solo, má qualidade da água e uma ameaça à biodiversidade local, sendo assim uma fase de "Pouca Resiliência".

Por outro lado, os ribeirinhos continuam dependentes de um conjunto de atividades, como o cultivo de espécies medicinais, especialmente hortelã (*Mentha* sp.), a pesca de peixes e camarão nos rios e igarapés, e o artesanato (Figura 5), possibilitando novas formas de adaptação. Isso levou a um bom grau de resiliência do sistema socioecológico, em face da quantidade de mudanças sofridas. Além disso, como as comunidades se organizaram e constituíram uma forma de assentamento que deu acesso a políticas públicas e apoio na produção, considera-se o assentamento como resiliente.

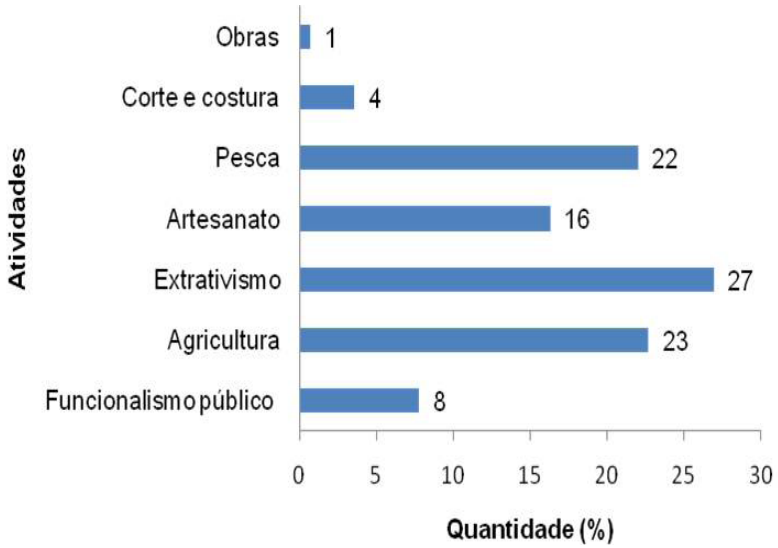


Figura 5 | Atividades desenvolvidas pelos ribeirinhos do assentamento São João Batista, Abaetetuba, Pará.

Sob a perspectiva social, a maioria dos comunitários permaneceu no assentamento e passou a exercer a atividade de extração de açaí, que está em expansão no município e foi resiliente às mudanças. A política de assentamento, de reforma agrária e de inclusão (como o Bolsa Família) certamente garantiu a segurança necessária no período de perturbações no SSE. Sob o ângulo ecológico, embora considerada uma atividade de baixo impacto, a exploração de açaí sofreu mudanças para atender ao aumento da demanda e, portanto, da pressão sobre as florestas de várzea, e do impacto sobre a biodiversidade e provisão de serviços ecossistêmicos.

A expansão do plantio de açaí para adensar as áreas naturais de florestas de várzea onde ele já ocorre naturalmente despontou como um novo caminho de desenvolvimento no PAE São João Batista. O açaí é uma espécie importante para a subsistência, para a renda da família e para garantir a ocupação da terra, e assinala o ponto de resiliência da comunidade, que manteve sua estrutura e adotou a exploração e comercialização do fruto para se auto-organizar (fase α do ciclo adaptativo). Existiu um potencial de mudança imprevista e rápida que resultou em um processo de *feedback* positivo, mantendo sua identidade (BUSCHBACHER *et al*., 2016). Entretanto, as consequências ambientais dessas mudanças têm alterado a biodiversidade e a paisagem local (GONÇALVES; BRASIL, 2016), sendo o atual modelo extrativista do açaí praticado pelas comunidades ribeirinhas da Amazônia (FREITAS *et al*., 2015).

3.3 AÇAIZAÇÃO E O FUTURO DO PAE

A crescente demanda comercial de açaí no Brasil e no exterior transformou-o na fonte principal de renda para os ribeirinhos do estuário amazônico, mas para sobreviver nesse mercado dinâmico, os agroextrativistas intensificaram o manejo do produto. As práticas do manejo do açaizeiro na várzea estuarina passam pelo desbaste das brotações e corte das árvores do entorno das touceiras dos açaizais, a fim de permitir maior entrada de luz, tornar a espécie mais competitiva e incluir transplantios de brotações das touceiras e plantios de mudas de açaizeiro dentro das áreas de ocorrência espontânea, conformando em áreas homogêneas de açaizeiro (TAGORE, 2017). Essa forma de manejo deixa o ambiente sujeito a ameaças que podem afetar o seu sistema ecológico, especialmente quando o açaí passa a ser a planta dominante no assentamento (Figura 6), fato que Hiraoka (1993) denomina de “açaização”.

Figura 6 | Presença expressiva do açaizeiro (*Euterpe oleracea* Mart.) na paisagem do PAE São João Batista, Ilha de Campompema, Abaetetuba, Pará.

Fonte: Elaborado pelos autores.

As consequências negativas do manejo intensivo do açaizeiro no PAE São João Batista já começam a ser apontadas pelos ribeirinhos, sendo recorrentes nas entrevistas verbalizações como: "*A terra começou a cair bastante devido o corte de paus" (N.C.N., 32 anos);* "*Terra tá baixando, as raízes das árvores tá muito em cima, aí perde as folhas, muito desmatado" (A.S.S.N., 64 anos)*; "*O açaí seca na árvore, pois tem poluição, desmatamento" (R.S.N., 74 anos)*; "*O açaí tá paroando e tá secando e cai" (J.M., 56 anos)*; "*Os animais estão diminuindo porque tão matando as árvores" (M.S.A.F., 55 anos)*.

A produção de frutos nativos decorrente quase que exclusivamente do extrativismo, a partir da década de 1990 passou a derivar também de açaizais nativos manejados e cultivados (NOGUEIRA *et al*., 1995). A possibilidade de ampliar a rentabilidade dos açaizais pelo manejo melhorou a renda das famílias e manteve a floresta em pé. De fato, a finalidade do manejo florestal em palmeiras é de proporcionar benefícios econômicos, ecológicos e sociais às comunidades tradicionais (JARDIM, 2002), por isso várias técnicas são utilizadas para que haja aumento na produção para incrementar o consumo e o comércio (SANTOS JÚNIOR *et al*., 2015).

Com o aumento da demanda pelo fruto do açaí, tem havido a retirada de quase toda a cobertura vegetal nativa para fazer "plantações" da palmeira (adensamento), resultando nas alterações percebidas pelos ribeirinhos e verbalizadas durante as entrevistas. A intensificação do manejo e exploração do açaí vem ocasionando perda de mais de 50% da diversidade de espécies de árvores e uma redução de 63% no número de espécies pioneiras (FREITAS *et al*., 2015). A retirada de espécies de árvores da várzea ocasiona o comprometimento da produção e da qualidade dos frutos do açaizeiro, pois o açaí tem forte dependência dos serviços ecossistêmicos como a polinização. Segundo Campbell *et al*. (2017), a visitação de abelhas, em particular, é maior em áreas de várzea cercadas por densa cobertura florestal.

Ainda sobre a supressão da vegetação nativa, as entrevistas evidenciaram desmatamento às margens dos rios com a extinção da mata ciliar, causando o assoreamento destes. Gonçalves e Brasil (2016) e Tagore *et al*. (2018) também constataram esse problema ambiental, e ressaltam que a derrubada das árvores nativas causa o enfraquecimento das encostas e assim a erosão e a deposição de grandes quantidades de sedimentos no leito dos rios.

As ameaças ambientais à várzea do estuário amazônico descritas anteriormente foram impulsionadas por uma política pública alicerçada no uso de recursos naturais. Se, por um lado, os ribeirinhos tiveram melhoria da infraestrutura de suas residências e embarcações com a implementação do PAE, além do financiamento produtivo que permitiu a expansão do mercado de açaí, por outro originou novos desafios para a conservação da várzea do estuário da Amazônia.

4 CONCLUSÃO

A história e a resiliência da comunidade do PAE São João Batista, Ilha de Campompema, Abaetetuba, Pará, se concebem em uma escala determinada, onde o ciclo adaptativo evidencia que a mudança (ou distúrbio) do sistema ocorreu devido ao declínio da produção canavieira. A transição do sistema econômico Cana-Açaí efetivou a capacidade dos ribeirinhos de experimentar mudanças e criar condições para se reorganizarem enquanto assentamento.

As fases do ciclo adaptativo de exploração e crescimento, ancoradas no uso e comercialização do açaí que o assentamento vivencia, classificam-no como resiliente. Entretanto, é importante salientar o papel das instituições locais, das políticas públicas e dos ribeirinhos no fortalecimento da resiliência, pois o desafio é torná-los capazes de enfrentar os períodos de instabilidade, aproveitando as oportunidades ocasionadas por suas atividades produtivas, como a pesca e o cultivo de outras espécies vegetais, o artesanato e a diversidade cultural.

No cenário atual de aumento na pressão sobre as florestas de várzea para produção de açaí, urge que se trabalhem ações coletivas para articular melhor a produção e comercialização, e criar novas relações socioecológicas. Isso iria assegurar a conservação e manutenção dos serviços ambientais da floresta de várzea, e a permanência e sustentabilidade das comunidades ribeirinhas que vivem do extrativismo do açaí em suas terras.

Considera-se que o ciclo adaptativo como modelo heurístico e a análise da resiliência são ferramentas úteis para estudar a trajetória de sistemas socioecológicos na Amazônia e para identificar possíveis fatores determinantes de suas mudanças e reorganizações, propiciando oportunidades para o planejamento em um contexto de rápidas e profundas mudanças no Antropoceno.

NOTAS

[1] Neste trabalho, de acordo com discussões de Lira e Chaves (2016), os termos "comunidade ribeirinha" e "ribeirinhos" s*ão* igualmente utilizados para representar os moradores que vivem no PAE São João Batista, cujo acesso só é realizado por via fluvial e o seu modo de vida é delineado pelo uso dos recursos florestais e aquáticos.

[2] *Avia*mento foi um sistema de crédito centrado numa casa comercial que funcionava anexada ao engenho, onde uma primitiva contabilidade registrava no "caderninho" as retiradas dos trabalhadores do engenho e sua produ*ção* na forma de um salário combinado com o dono do engenho. Ao final do mês havia o acerto de contas, em que as retiradas eram abatidas da remuneração devida ao trabalhador (MACHADO, 2008).

[3] *Bolsa Família é* um programa de transferência condicional de renda destinada às famílias pobres que cumprissem com certas condições relacionadas à saúde e educação (SILVA; PAES, 2019).

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From the Roman Empire to Rio de Janeiro: society and models of sustainable water management

Do Império Romano ao Rio de Janeiro: a sociedade e os modelos sustentáveis de gestão das águas

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doi:10.18472/SustDeb.v12n2.2021.38769

Received: 30/06/2021
Accepted: 01/08/2021

ARTICLE – VARIA

ABSTRACT

The purpose of this article is to carry out a content analysis around the historical influence of ancient societies' ideas regarding sustainable water management. Ancient civilizations developed models and practices for the drainage, intake and transport of rainwater and wastewater. Despite the Roman Empire and the Moorish domination, Lisbon maintained its characteristics until the formation of the Kingdom of Portugal, undergoing an urban and sanitary revolution, which lasted until the 19th Century, when the Portuguese Royal Family moved to Brazil. Rio de Janeiro was chosen as the capital of the Kingdom of Portugal, undergoing several alterations inherited from the models and practices of irrigation techniques, hydraulic engineering and architecture of Lisbon. Data compilation in electronic spreadsheets and the use of NVivo software facilitated organizing the information and conclude that sustainable management models can be replicated as an inheritance of ancient societies.

Keywords: Roman Empire. The Kingdom of Portugal. Rio de Janeiro. Water Management. Sustainability.

RESUMO

O objetivo deste artigo é realizar uma análise de conteúdo da influência histórica dos pensamentos das sociedades antigas em relação à gestão sustentável das águas das chuvas. As antigas civilizações desenvolveram modelos e práticas de drenagem, captação e transporte das águas pluviais e águas servidas. Apesar do Império Romano e da dominação moura, Lisboa manteve suas características até a formação do Reino de Portugal, passando por uma revolução urbanística e sanitária, que se estendeu até o século XIX, quando a Família Real Portuguesa mudou para o Brasil. O Rio de Janeiro foi escolhido como a capital do Reino de Portugal, sofrendo diversas transformações herdadas dos modelos e práticas das técnicas de irrigação, engenharia hidráulica e arquitetura de Lisboa. A compilação de dados em planilhas eletrônicas e o uso do software NVivo facilitaram a organização das informações, concluindo que modelos de gestão sustentável podem ser replicados pela história das sociedades.

Palavras-chave: Império Romano. Reino de Portugal. Rio de Janeiro. Gestão das Águas. Sustentabilidade.

1 INTRODUCTION

The evolution of man in political, social, economic, historical, or cultural terms should be viewed from the perspective of the historical period of mankind and the division of history into different eras, as a means of creating a background that is conducive to understanding how society itself has evolved.

This evolution can be understood through a division of the past into classical periods and investigating various aspects of society, such as man´s first experiences of socializing and living in communities, the first records of artistic and religious expression. It also requires an explanation of the lengthy wars for territory, the creation of currencies, economics, etc. (POMIAN, 1993).

Among examples of the evolution of societies, the Roman Empire can be mentioned as the most powerful empire in the ancient world, reaching 21% of the world population and capable of developing art, science and politics in a way never seen before. (VALE, 2019).

According to Vale (2019), despite the residential buildings, Ancient Rome stood out because of its great monuments and engineering works, especially: roads, bridges, arches, etc. However, the most important urban project was the implementation of the sanitation system, which included the construction of aqueducts, public cesspools, and the rainwater drainage system.

The concept of drainage can be attributed to a set of implements that could be used for agriculture and were designed to meet the needs of crop irrigation. Following the rise of new civilizations, new drainage models and practices began to be developed, such as the regulation of soil moisture, the alteration of river beds in areas destined for occupation, and practices of collecting and transporting rainwater and wastewater (FERNANDES, 2002).

Man's relationship with water is intricately linked to changes in behaviour which began in the Paleolithic Age among small groups of nomads who later formed larger communities and settled on the land. Setting out from the cultivation of wheat and barley, irrigation techniques emerged which allowed settled communities to move on, initiate a more sedentary life and give rise to the first structured villages.

The Age of Discovery and the Renaissance were closely observed as interconnected phenomena that contributed to the dismantling of the medieval structure and the composing of modern society in Western Europe, promoting the social transformations that influenced the colonized territories (DUTRA, 2013).

In this historical context, the city of Rio de Janeiro appears as an alternative for Portugal in the face of Napoleonic conquests in the early 19th Century, becoming the capital of the Kingdom of Portugal, Brazil and Algarves between 1815 and 1821, promoting great urban and sanitary transformations (SILVA, 2009).

The content analysis of this study is part of the doctorate research, which seeks to identify a historical correlation between the management models implemented in cities of the ancient Roman Empire and in Rio de Janeiro to justify the influence of societies on issues related to sustainability and water management.

2 METHODOLOGICAL PROCEDURES

This research seeks to correlate the historical influence of rainwater management models implemented in the city of Rio de Janeiro by Portuguese colonizers, to models and techniques from the cities of the Roman Empire. The research is conceptualized under a qualitative, descriptive, and interpretive approach to the theme "sustainable rainwater management".

As proposed by Bardin (2011), qualitative content analysis is structured in three stages: organization, coding, and categorization of information, that results in an analytical generalization, capable of allowing the replication of the method, without necessarily requiring quantitative complementation of the theme.

Descriptive research deals with an in-depth analysis of researched reality. It aims to identify correlations between various sources with a focus on the description, classification and interpretation of facts. Assuming that, models or frameworks are proposed from the observation and comprehension of a given phenomenon, which makes them capable of supporting and validating the proposed hypotheses (RUDIO, 1985).

As states Schwandt (1994), an interpretive approach seeks to understand the world from the point of view of those who experience it. It allows understanding the research object as a result of social interaction shaped by the actors involved, through a rereading of the meanings of the phenomena and the observed historical events.

Bardin (2011) defines content analysis as a set of tools of a methodological nature in constant improvement and applied to diverse content and continents.

Data were obtained in the pre-analysis phase through electronic consultation of open access journals available on academic research portals such as BDTD (Digital Library of Theses and Dissertations), ERIC (Education Resources Information Center), Google Books, Google Scholar, JURN, Portal Periodicals Capes, SciELO (Scientific Electronic Library On-line), SCIRUS, SPELL (Scientific Periodicals Electronic Library) and The British Library.

Taking advantage of the option of advanced criteria in the research portals, the authors performed a second search guided by Boolean logic, which deals with a type of information retrieval system, in which two or more terms are combined, relating them by logical operators, and that makes the search more restricted or detailed (FERNEDA, 2003).

The advanced criteria of searching created links between the theme of "sustainable rainwater management" with the ideas of: "Roman Empire" and "Kingdom of Portugal", "Lusitania" and "Roman Empire", "Lisbon" and "Augusta Emerita", "Portugal" and "Age of Discovery", and "Rio de Janeiro" and "Lisbon"; from the use of the operators "and", "or", "and/or" and "not".

Data were compiled using electronic spreadsheets and cross-reference tables which served as input to the NVivo software (version 11). This software was chosen to support the research, performing the tasks of finding, analyzing, and organizing the information in the documents such as scientific papers

and articles, magazines, newspapers, and web content, according to the relevance and adherence to the theme, whose results can be seen in Table 1 below.

Table 1 | Result of the content analysis of the theme "sustainable rainwater management", according to the relevance and adherence to the links obtained from the advanced search criteria (2010-2020).

Links	*Number of documents*	*Relevance and adherence to the theme (%)*[1]
"Roman Empire" and "Kingdom of Portugal"	7.315	24,59
"Lusitania" and "Roman Empire"	6.149	20,67
"Lisbon" and "Augusta Emerita"	5.887	19,79
"Portugal" and "Age of Discovery"	3.789	12,74
"Rio de Janeiro" and "Lisbon"	4.125	13,87
"rainwater" and "sustainable management"	2.478	8,33
Total of documentary sources	*29.743*	–

Note:

[1]*Percentage determined by the ratio between the total of documents analyzed in a link and the total of documents sources analyzed.*

Source: Prepared by the authors, 2021.

The content analysis was linked to the theme "sustainable rainwater management" and resulted in 29,743 documents which were processed by the NVivo software according to the relevance and adherence, which percentage was determined by the ratio between the total of documents analyzed in a link and the total of documents sources analyzed obtained from the advanced search criteria from 2010 to 2020.

Finally, the content analysis allowed us to include a historical exploration in the literature review of the thesis, to narrow the perception of the influence of the thoughts of ancient societies, and the water management models and practices adopted by the Kingdom of Portugal in Rio de Janeiro.

3 FROM ANTIQUITY TO THE ROMAN EMPIRE

According to Morris (1998) – and in contrast with the division of history into classical periods put forward by the Polish historian, Pomian (1993) – the establishment of the first urban civilizations took place during the Bronze Age (3500-3000 B.C.), and lasted for more than 2000 years.

Certain archaeological studies state that the first civilizations arose in the following regions: the South of Mesopotamia (Egypt); the Indus River Valley (Pakistan); the Yellow River (China); the Valley of Mexico; the forests of Guatemala and Honduras; and the coast and plateau of Peru (DANIEL, 1968).

According to Mc-Neill (1998), communities began to be structured as City-States and then displayed political, social, cultural, religious, economic, and urban features and implicit in these radical changes was the most important fact in the history of mankind: the appearance of civilization in the Minoan Civilization (in the Greek island of Crete); in ancient Syria; in Egypt (North-East of Africa) and Sumeria (in lower and mid-Mesopotamia, now the South of Iraq and Kuwait).

The Sumerians (3500 B.C.) increased the extent of irrigated farming because they mastered the techniques of drainage by diverting water from the Tigris River and Euphrates. In this way, they could cultivate vast stretches of alluvial desert and transform a previously arid plain into fertile farmland. Since they were occupying areas that were subject to constant flooding, the Sumerians were compelled to carry out huge engineering works such as large dykes.

Moreover, to broaden their knowledge of architecture, Sumerians began to build magnificent towns and cities along the riverbanks. These were surrounded by thick walls and inside there were palaces, imposing temples and mansions with walls built of masonry and comfortable houses alongside numerous streets (FERNANDES, 2002).

Similarly, important towns and cities began to emerge along the banks of the Nile River (Egypt) and its plains, which had a surplus agricultural production that was able to support the business activities in the region. The Egyptian civilization was based on a strict social stratification where power was concentrated in the hands of the Pharoah, whereas in the Sumerian civilization power was based on independent City-States (MORRIS, 1998).

Archaeological studies have confirmed that civilization began in the Indus River Valley (3500-1700 B.C.), which comprises an area that includes the North-East of Afghanistan, the greater part of Pakistan and the West and North-West of India. Networks of drainage systems have been discovered in three cities of Harappa, – Mehrgarh and Mohenjo-Daro (Pakistan) and Lothal (India). These were built with great care and were designed to transport rainwater or wastewater and to protect the cities from floodings caused by the thaw that followed the icy season of the Himalayas (WRIGHT, 2010).

New concepts of drainage systems were adopted in these cities at that time, and these involved laying blocks of stones to surround the areas and form elevated walls, to reduce the surface run-off of the rainwater and ensure it could be stored. The rest of the city was built at a lower level and was also surrounded by walls which allowed the citizens to enjoy a rare amenity in ancient times – running water. (MORRIS, 1998).

The drainage system adopted in these civilizations was adapted to farming practices and the way the people settled on the river banks so they could make use of the fertility of the alluvial soil for producing food. The growth of agriculture led to an increase in the population and hence, it became necessary to produce more food. This was achieved based on advances made in the technology of drainage systems, since land that had previously been barren, could be used for agricultural purposes.

The Bronze Age witnessed the rise of the island of Crete: the Minoan Civilization (2700-1450 B.C.), with the city of Knossos, where the topography and soil were suited to farming based on the cultivation of wheat and lentils. Owing to its surplus production and its ideal geographical position, the Minoans were able to carry out trade on a large scale with the civilizations of the Western Mediterranean and Eastern Europe (GRAY, 1940).

Among the ruins of the Palace of Knossos, a stonework system was found comprising well-planned towns, cobbled streets, gutters, small shops and residential districts. In addition, the “palace-city” had three separate systems for water management, each of which was designed for supply, drainage of run-off and drainage of wastewater. This system is now recognized as an “absolute separator” and would serve as an inspirational model for the Romans in the future (GRAY, 1940).

Numerous references to water, of every kind of representation, can be found in the history of ancient civilizations, such as cave paintings, records of signs, cultural or religious traditions, etc. In the case of the Persian civilization, rainwater was regarded as sacred and polluting it was a sin. Rainwater was stored in cisterns and used as a source of supply.

Even though there are many different records, the “cradle of civilization” can be regarded as being located in the region of Mesopotamia, which in its etymological origins means a “country situated between two rivers”, namely, the Tigris River and Euphrates River – and for the ancient Greeks, this region belonged to the so-called Fertile Crescent (ISSAWI, 1988).

The rise of the Roman Empire which was responsible for creating one of the greatest civilizations in history can be viewed as one of the finest achievements of mankind. At its peak, it was the most extensive of any empire in the ancient world and its size was never previously witnessed in ancient history.

The domination of Rome (Figure 1), which had a population that reached a million inhabitants lasted for about five centuries (27 B.C. – 476 A.D.) and extended from the Rhine River to Egypt and from Great Britain to Asia Minor, thus forging a link between Europe, Asia and Africa (GIBBON, 1996).

Figure 1 | The Eastern and Western regions of the Roman Empire

Source: Adapted from Gibbon, 2021

In the political system of the Roman Empire power was concentrated in the figure of the emperor – from Augustus to Constantine the Great – with the political support of the Senate, which was a legacy of the ancient Roman Republic. As a result of the new system, Rome, a City-State, began to be governed by the emperor and to benefit from technological advances made at that time, from matters related to philosophy and medicine or architecture and engineering.

The Romans built systems of carefully planned roads that included conduits for the surface run-off of rainwater and in this way, they were able to drain their roads. In addition, cisterns were built with communicating chambers and apertures on the roof which were designed to collect and supply water to the cities and ports. The water tanks of that time are an example of how the concepts of hydraulic engineering were preserved (HILL, 1984).

The Romans also built a complex sewerage system made up of open channels and underground ducts for transporting effluent known as "*cloaca*", the largest of these being the "*Cloaca Maxima*", which was a public project planned by Etruscan engineers and built by the manpower of the working-class in Rome. This sewerage system was responsible for the drainage of the surrounding region of the Forum extending to the Tiber River (GIBBON, 1996).

4 AUGUSTA EMERITA – THE CAPITAL OF LUSITANIA

When the Eastern region of the Roman Empire was under the rule of Emperor Augustus (27 B.C.–14 A.D.), there was a series of conquests in the European continent which reached Hispanium, the name given by the Romans to the Iberian Peninsula (currently comprising Portugal, Spain, Andorra, Gibraltar, and a small part of the South of France). Hispanium was divided into three provinces (Figure 2): Baetica and Lusitania (Hispania Ulterior) and Hispania Tarraconensis (Hispania Citerior) (LEÃO, 2015).

Figure 2 | Hispania (Iberian Peninsula) during the Roman Empire

Source: Adapted from Leão (2015).

Emperor Augustus pursued an expansionist policy to extend Roman domination and founded the following colonies: Augusta Emerita (now Merida) in 27 B.C.; Bracara Augusta (now Braga) in 16 B.C.; Asturica Augusta (now Astorga) in 14 B.C., which had considerable administrative importance as a centre for the control of gold mining; Hispalis (now Seville), and Gades (now Cadiz), from where the gold was shipped to Rome (LEÃO, 2015).

The colony of Augusta Emerita was founded to provide a place for settling war veterans who came from different regions of the Roman Empire. It became the capital of Lusitania since it was a strategic enclave on the banks of the Guadiana River. This meant it could communicate with other colonies through the roads which linked the Baetica province with provinces of the North-East peninsula and with the strips of land in the South of Hispania and the city of Felicitas Julia Olissipo (now Lisbon) (MANTAS, 2004).

Augusta Emerita began to include the essential and indispensable framework required for the institutional facilities of the recently created province of Lusitania: the abode of the magistrates, the public archives, the financial services, etc. Given this, the decision-making of the new colony adopted the regional policies of the Roman Empire and confirmed it was committed to acting as a provincial capital. This entailed following the parameters laid down by the Romans for urban planning and administrative

responsibilities for the territory and as a result was able to ´romanize´ the territorial extension of the Eastern peninsula by reproducing the architectural and urban features of Rome (BORGES, 2016).

Although Augusta Emerita was far away from the splendour of the Italian or Western cities of the Roman Empire and Lusitania was still regarded as a distant province, it was not an isolated territory that was cut off from the Mediterranean world. The economic and strategic importance of Lusitania and its provincial products meant that it stood out from the other Roman colonies (MANTAS, 2004).

It should be noted that the growth of the towns and cities in Lusitania had to be accompanied by irrigation techniques, hydraulic engineering and Roman architecture. This made Augusta Emerita a showcase for the Roman Empire since the principle of urbanism that was instilled in that colony as a dominance strategy, enabled the process of "romanization" to become widespread and the concepts of imperial power and culture to be merged in the region of Hispania (BORGES, 2016).

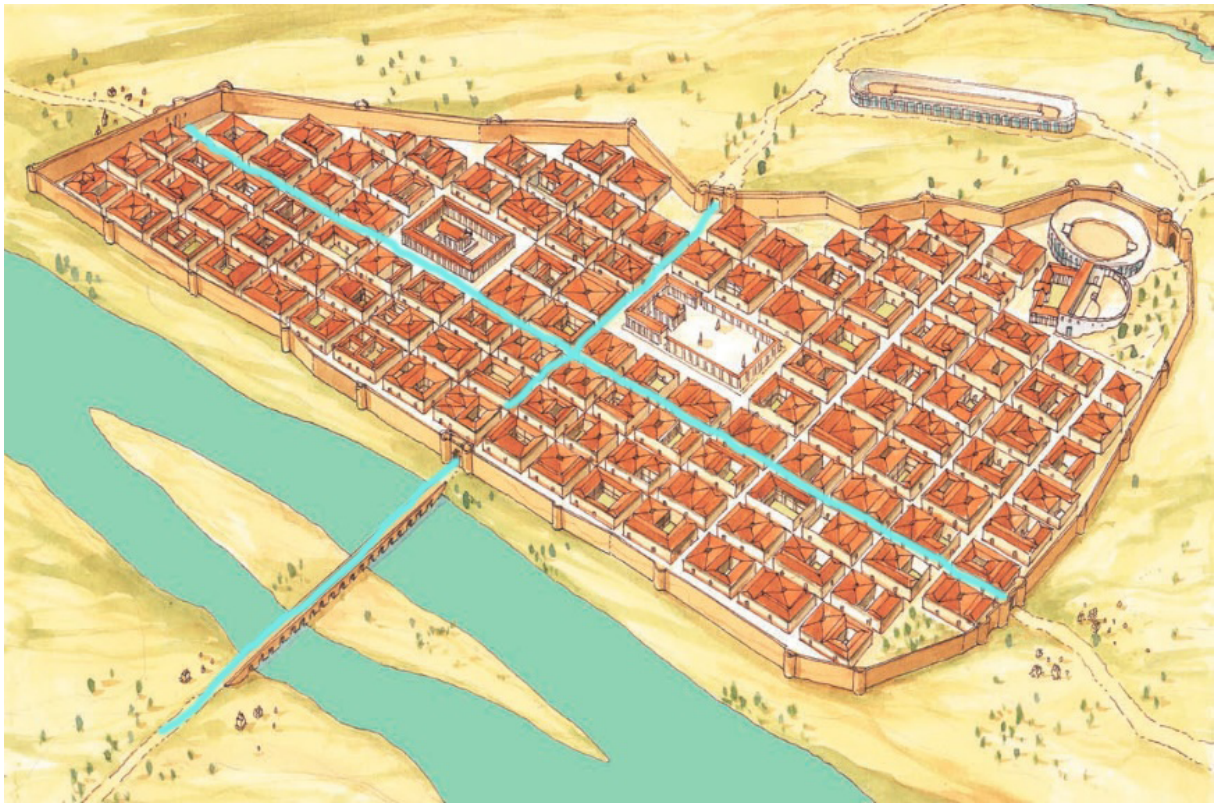

Figure 3 | Artistic representation of Augusta Emerita

Source: Adapted from Rome on Rome, 2021

Figure 3 (above) is a representation of Augusta Emerita when it became one of the main towns of Roman Hispania with an area of about 20.000km² and its water distribution system followed the models employed in Rome. It involved the building of dams (the Proserpina and Cornalvo dams) and aqueducts (Aqueduct of Los Milagros, Acqua Augusta and Rabo de Buey-San Lazaro), as well as bridges and arches, which allowed water to be distributed from the spas and springs of the city (LEÃO, 2015).

Thus, it is worth underlining the importance of Felicitas Julia Olissipo (now Lisbon). During the period of Roman domination, it became a maritime centre for the Atlantic Ocean. This was because the estuary of the Tagus River gave protection to the ships, provided access to deep-draught embarkation, as well as offering a means of communicating with the interior of the peninsula. In addition, the maritime route from Cadiz to Lisbon allowed agricultural products to be transported from the Guadalquivir River valley

to regions in the north and middle of Hispania, thus strengthening the ties between the Mediterranean world and the Atlantic Ocean (MENDES, 2014).

The end of Roman Hispania Romana was brought about by the weakening of the Roman Empire around 255 A.D., when there were invasions from the South by the Vandals, from the North of Lusitania by the Swabians and the centre of the region by the Alans. Most of the towns of Europe shrank in size when their residents fled from the urban centres where there was insecurity and a state of anarchy. This was followed by robbery and plunder as the outskirts and rural areas became occupied, resulting in mass emigration (BISHOP, 1968).

Rome attempted to re-establish order in Hispania by forming a truce with the Visigoths, but this soon became unstuck on account of the excessive taxes levied by the decadent Empire. After the disappearance of the Roman institutions, the Swabians, followed by the Visigoths, adopted an ecclesiastical system as their administrative model, which was a means of ensuring stability and established one of the first Christian kingdoms in Europe (BARBERO; LORING, 2005).

The Swabians and Visigoths filled in the power vacuum left by the Roman administrators and thus maintained their standards with a high degree of centralized power in their capitals, Braga and Toledo, respectively. Despite their fall from power, Roman law remained in the Visigoth Code and Hispania maintained the infrastructure of the cities such as roads, bridges, aqueducts and irrigation and drainage systems (BARBERO; LORING, 2005).

The dominance of the Visigoths ended with the Islamic invasion of the Iberian Peninsula – the so-called Arab Conquest – when troops coming from North Africa crossed the straits of Gibraltar (711-726 A.D.), resulting in serious population displacements and the conquest of the peninsula (AFONSO, 1972).

The Moors governed the peninsula for 800 years after seizing the territory that they called "*al-Andalus*", because of their military and territorial dominance and this led to a blending of peoples and cultures of very heterogeneous social origins. However, they kept the main part of the Roman legacy, by repairing and extending the inherited infrastructure and making use of it for irrigation while introducing new farming practices and new products, such as rice, sugar cane, citrus fruit, apricots and cotton (CHACON, 2005).

The "Reconquest" – as some historians dubbed the attack against the Moors – was concluded at the beginning of the Modern Age when the Catholic monarchs, Fernando of Aragon and Isabel of Castile, brought about the final expulsion of the Moslems, in 1492. However, the Moors left the Iberian Peninsula a valuable cultural heritage and progressive scientific knowledge which was characterized by their architecture and naval engineering which would contribute to the founding of the future empires established by the Portuguese and Spanish discoveries (LOMAX, 1978).

5 THE KINGDOM OF PORTUGAL AND THE AGE OF DISCOVERY

The features of Felicitas Julia Olissipo were radically changed by the crisis in Roman society and the physiognomy underwent great alterations, mainly due to the conquest of the Visigoths. They gave the name of *"Ulishbon"* to the main port, and this was subsequently altered by the Arabs to *"Lušbūna"* or *"al-Ushbuna"*, which is now called Lisbon [*Lisboa*] (SILVA, 2008).

After the reconquest of the Iberian Peninsula and the founding of the Kingdom of Portugal in the 12th Century, D. Afonso Henriques – the first king of Portugal – began to administer the new socio-economic policies based on the feudal system and Lisbon replaced Coimbra as the capital of the kingdom and most important city in the region.

At that time, water was an essential element in economic development and, thus, windmills and watermills were designed to act as the mainspring for grinding corn, weaving, dyeing, and tanning – all activities that had profound effects on the properties of the feudal lords.

The region of Lisbon had a large population and there was a constant problem caused by the scarcity of drinking water, despite the presence of the Tagus River, which had high levels of salinity that made the water unsuitable for human consumption. The only district of Lisbon with available springs was Alfama, so this meant it was necessary to obtain water from far away places like the ravine of Ribeira de Carenque, in the region of Belas, where the water had been used by the Romans, who had built a dam and an aqueduct there (CASEIRO, 1999).

As states, Caseiro (1999), the Aqueduct of Free Waters [*Aqueduto das Águas Livres*] is a complex stonework system for the intake, adduction, and distribution of water, and this supplied water to the city of Lisbon through a network of fountains and water sources through the force of gravity and comprised a total of approximately 58 km of underground tunnels and upper galleries.

During this period, Portugal became the leading navigational power in the world and was a pioneer in so far as it was the first country to transform the discoveries of technological and scientific research into State policies. In this way, it paved the way for Aragonese and Catalans, to enhance the nautical knowledge of the naval officers and simple sailors which culminated in, for example, the discovery of the archipelagos of the Azores, Madeira and the Canary Islands, Brazil in South America and a vast territory in Asia (CHACON, 2005).

In the history of Lisbon, an earthquake followed by a tsunami, and the outbreak of fires that occurred on 1st November 1755, destroyed most of the city. Curiously, the Aqueduct of Free Waters was not affected by the seismic event. King D. José I granted absolute powers to Sebastião José de Carvalho e Melo, the future Marquis de Pombal, who restored the city by employing engineers and architects to undertake a work of urban regeneration (TAVARES, 2005).

The reconstruction of Lisbon was funded by the wealth of the colonies, particularly Brazil where excessive taxes were levied in exchange for special privileges such as the granting of lease contracts and royal bounties, giving the elite the most profitable trading concessions of the Crown (ROMEIRO; BOTELHO, 2003).

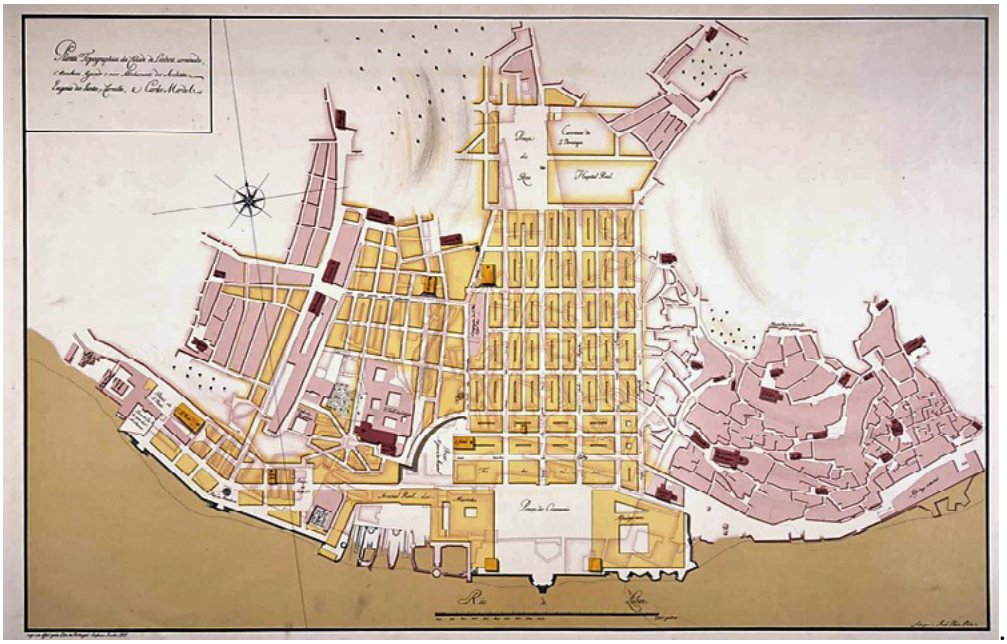

Figure 4 | "Pombaline" Lisbon
Source: Adapted from Museum of Lisbon (2021)

The plan to reconstruct Lisbon followed the pattern of a checkered outline (Figure 4) which extended from Rossio Square to Terreiro do Paço and included the streets alongside the Tagus River and architecture based on rational concepts and the ideas of the Enlightenment which were becoming widespread at that time (FONSECA, 2005).

The sanitary sewage system and the means of distributing water were redesigned to cater to the needs of the modern city that had arisen. These were based on the new methods of calculating the speed of the surface run-off and leaks that emerged in the Modern Age and survived into the 19th Century. Moreover, it was established that rivers, springs and underground waters were formed from rainwater. (FONSECA, 2005).

6 RIO DE JANEIRO – THE CAPITAL OF PORTUGAL

At the beginning of the 19th Century, a large part of Europe was under the dominion of France and governed by Napoleon Bonaparte, proclaimed emperor in 1804. The main strategy of the French government was the Decree of the Continental Blockade in 1806, which brought into effect a large-scale trade embargo against the British Isles.

However, the government of Portugal was reluctant to adhere to the Blockade on account of its longstanding traditional ties with England on which it depended a great deal economically. The Prince Regent Dom João VI was in a delicate situation and "was uncertain about which alternative strategy would be most damaging to the Portuguese monarchy" (MATTOS, 2017).

The everyday life of Lisbon was greatly affected by the rumours of an imminent French invasion and there was an increasing sense of insecurity. For this reason, a planned course of action began to gather momentum – to transfer the court of the Portuguese monarchy to Brazil. In light of this, a strategic plan of escape was put into effect on the morning of 29th November 1807, when the Prince Regent went on board the *Nau Capitânia*, and accompanied by English vessels, finally left Lisbon on course for Rio de Janeiro (MATTOS, 1995).

The arrival of the Portuguese Royal Family in Rio de Janeiro, at the beginning of the 19th Century, was a significant social event and led to radical changes which were aimed at turning the colonized city into a metropolis. The Prince Regent promulgated the Royal Charter for the Opening of Ports to Friendly Nations [*Carta Régia de Abertura dos Portos às Nações Amigas*] four days after his arrival and as a result of this act, Brazilian towns and cities began to acquire great social and economic importance since it meant the end of the Colonial Pact and allowed freedom of trade with other countries (MATTOS, 1995).

The choice of Rio de Janeiro followed key criteria because it was the most populous and economically important Brazilian city, as well as having a wealthy elite of traders and a powerful naval industry. In addition, Rio de Janeiro was endowed with a reasonable system of defence since it housed a large military contingent of captaincies and was one of the headquarters of the Portuguese naval squadrons in Brazil (CAVALCANTI, 2004).

In 1808, approximately 865 vessels went to the port of Rio de Janeiro filled with merchandise and an assortment of novelties of various nationalities which represented a significantly large number for that time. On the other hand, the Europeans were dazzled by the exoticism of the natural surroundings, while on the other they were frightened of the urban crowds flocking around them (SILVA, 2009).

As well as changes in architecture and engineering, the new features introduced or inspired by D. João VI included the foundation of the Imperial School of Arts and Crafts, the French Artistic Mission, the Royal Printing Press, the National Library, the Botanical Gardens, the Military Archives, the Naval Academy, the Bank of Brazil, and the Munitions Factory, as well as newspapers, schools, museums, theatres, etc. (HEYNEMANN; VALE, 2010).

A decree was promulgated for the Supervision of Court Police on 10th May 1808, which was a public body with responsibilities like those currently carried out by the City Council. In a similar way to its counterpart in Lisbon, the body began to be responsible for the following: security, criminal investigation, arresting criminals undertaking public works, protecting supplies, and dealing with matters linked to public order (HEYNEMANN; VALE, 2010).

The urban space of Rio de Janeiro was altered in a relatively short time under the command of the Conde dos Arcos, who was the last viceroy of Brazil. The old streets which had previously been bumpy and neglected were covered in new paving to make it easier to travel in carriages, which now began to appear in all directions. The streets and roads were open so there could be a surface runoff and allow the products grown in areas close to the city to be transported to meet the needs of the Court. Public lighting began to appear throughout the city, and whale oil was used in the lampposts, squares and public gardens which led to an alteration in the everyday lives of locals. (SILVA, 2009).

The water resource management of the city was under the command of the Parliamentary Chamber. This applied the principles inherited from the engineers and architects who had been responsible for the reconstruction of Lisbon. They formed landfills and drained many swamps such as the Campo de Santana, which operated as a dumping ground and had large cesspits and ditches.

The system for supplying water in Rio de Janeiro consisted of the aqueduct and fountain of *Carioca* and was extended through the construction of new bridges, springs and fountains, as well as by increasing the capacity of the already existing *Chafariz do Carmo*. (HEYNEMANN; VALE, 2010).

Rio de Janeiro was the capital of the Kingdom of Portugal, Brazil and the Algarves between 1815 and 1821, when D. João VI returned to Portugal, leaving an altogether different city to be governed by his son D. Pedro de Alcântara – D. Pedro I (SILVA, 2009).

7 SUSTAINABILITY – A HISTORICAL PROCESS

The influence of ancient societies went beyond the limits of culture, language, religion, and arts, and reached the thoughts of public administrators who formalized policies aimed at the domain of the territory and economic development (POMIAN, 1993).

The action of people on nature, since the most primitive society, has resulted in environmental degradation, under the justification of the need to produce food, consumer goods, energy, build cities, etc. In this process, water has always been the most important natural resource, generating conflicts of interest that did not exist until then.

There are some records from antiquity reporting the concern of some public administrators in the preservation of forests as regulators of the water cycle and in protecting soils against erosion, such as the writings of Plato in 4 B.C. complaining about the devastation of landscapes in Greece (BORGES; MARCÍLIO, 2021).

During the period of development of territories and cities, environmental sustainability never had its importance considered in the management and the urbanization models implemented, and its importance was given through a long historical process, going from the “conqueror” to the “conquered”, small ecological practices and sustainable experiences replicated in each region, according to its characteristics.

8 FINAL CONSIDERATIONS

As the result of doctorate reflections, this article presents a theoretical discussion on the influence of the thoughts of ancient societies. This analytical-discursive research allowed us to observe a historical correlation between management models implemented in cities of the ancient Roman Empire and Rio de Janeiro.

The content analysis carried out under the methodology described by Laurence Bardin created links between the theme "sustainability" and "rainwater management" with the historical contribution of Portuguese colonization, from the Roman domination to the arrival of the Royal Family in Rio de Janeiro, including the Moorish domain of the Iberian Peninsula.

Analyzed data confirmed that the Roman culture significantly influenced the Mediterranean world, constituting a solid model for the entire Western civilization, as attested by Locatteli and Schörner (2009). This observation allowed us to verify the relevance of studying the history of ancient civilizations for understanding the models inherited by the current contemporary society.

It can be concluded that the influence of the ideas of societies, referring to politics, culture, art, architecture and engineering cut across time and space. Thus, they can allow progress to be made in terms of innovative ideas and engineering techniques that are strengthened by traditional knowledge and can alter the environmental conditions where they prevail.

In addition, the relationship between the models for water management adopted and put into effect by the Kingdom of Portugal, and the techniques for the intake, storage and supply of water and sewage disposal were inherited from the Roman Empire. Years later, they crossed the Atlantic Ocean with the Portuguese Royal Family and changed the way of life and standard of living of the inhabitants of Rio de Janeiro.

Finally, it can be concluded that the process of raising heightened awareness and alteration of the characteristics of the water system must be continuous. Moreover, the inclusion of the historical background and social participation should be regarded as a positive factor in ensuring the improvement and success of the models for water resource management in any region.

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Classificatory disputes and scientific controversies: society, nature, and culture in the Anthropocene

Disputas classificatórias e controvérsias científicas: sociedade, natureza e cultura no Antropoceno

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doi: 10.18472/SustDeb.v12n2.2021.34395

Received: 28/09/2020
Accepted: 31/03/2021

ARTICLE – VARIA

ABSTRACT

In general, the idea of Anthropocene refers to the set of socio-historical, ecological, economic, and technological transformations responsible for configuring a new stage of regulation and evolution of the planetary geological system. From its original proposition in the 2000s, this notion gained increasing repercussion, mobilizing different positions in multiple fields of scientific knowledge. This article aims to develop a critical analysis of some of the main concepts found in such debates, from the mobilization of three fundamental analytical categories: the concepts of Society, Nature, and Culture. In methodological terms, this is a literature review article based on qualitative and non-systematic bibliographic research. The analysis undertaken here indicates how the different approaches mobilized by the driving idea of Anthropocene result in theoretical movements that redefine the relationships between agency, structure, and social change in the historical context of modern industrial societies.

Keywords: Anthropocene. Sustainability. Social Theory. Climate Change.

RESUMO

De maneira geral, a ideia de Antropoceno faz referência ao conjunto de transformações sócio-históricas, ecológicas, econômicas e tecnológicas responsáveis por configurar uma nova etapa de regulação e evolução do sistema geológico planetário. A partir de sua proposição original nos anos

2000, essa noção ganhou repercussão cada vez maior, mobilizando posicionamentos díspares em múltiplos campos do conhecimento científico. Este artigo tem como objetivo desenvolver análise crítica a respeito de algumas das principais concepções encontradas em tais debates, a partir da mobilização de três categorias analíticas fundamentais: os conceitos de Sociedade, Natureza e Cultura. Em termos metodológicos, trata-se de artigo de revisão da literatura, a partir de pesquisa bibliográfica de caráter qualitativo e não sistemático. A análise empreendida indica como as diferentes abordagens mobilizadas pela ideia-força de Antropoceno implicam movimentos teóricos de redefinição das relações entre agência, estrutura e mudança social no contexto histórico das sociedades industriais modernas.

Palavras-chave: Antropoceno. Sustentabilidade. Teoria Social. Mudanças Climáticas.

1 INTRODUCTION

Since its presentation in the early 2000s, the idea of Anthropocene has gained enormous repercussion and popularity in scientific debate forums, as well as in cultural and media spaces of social communication (CRUTZEN, 2002; CRUTZEN; STOERMER, 2000; MONASTERSKY, 2015; STEFFEN *et al*., 2011, 2015; TRISCHLER, 2016). In academic terms, this importance is expressed, for instance, in the release and publication of scientific journals exclusively dedicated to the theme: "*The Anthropocene*," "*Elementa: Science of the Anthropocene*," and "*The Anthropocene Review*". In addition, artists and architects have responded to the implications of this discussion in their professional practice, poets and writers translate their concepts into literary productions and invite academics and ecocritics to reflect on similar cultural translation practices (LEWIS; MASLIM, 2015; TRISCHLER, 2016).

In general, the idea of Anthropocene refers to the set of social, historical, ecological, economic, political, cultural, and technological transformations responsible for configuring a new stage of regulation and evolution of the planetary geological system. Its fundamental premise is based on observations, measurements, trend studies, and records that indicate the occurrence and intensification of multiple processes of imbalance, exploitation, and disturbance in the dynamics of ecosystem regulation at the most different planetary scales (ARTAXO, 2014; CRUTZEN, 2002; CRUTZEN; STOERMER, 2000; ROCKSTRÖM *et al*., 2009; STEFFEN *et al*., 2011, 2015; ZALASIEWICZ *et al*., 2017, 2018). In contrast to the Holocene period, the human species would come to be seen as a force acting on a geological scale, from its intensive activities and interactions with the biophysical environment. In this sense, anthropic actions become so broad and deep that they assume characteristics of rivalry to the great forces of Nature, pushing the Earth system towards the uncertain and unknown (STEFFEN; CRUTZEN; MCNEILL, 2007).

As such, the discussion around an Age of Humans seems to operate from the split established between society (or culture) and nature (or biophysical environment) (CHAKRABARTY, 2009, 2018; LATOUR, 1994, 2012, 2014, 2017; LEWIS; MASLIM, 2015; TRISCHLER, 2016). In other words, it is as if the capacity for human organization and activity assumed a position of independence from the limitations previously established by the physical, biological, and natural dimensions that structured human existence. From an increasingly specialized and concentrated power of manipulation and transformation, humanity re-articulates its place in the landscape of the evolution of species, often placing itself in a position of domination and/or control of the forces, processes, and phenomena typically characterized as natural (CRUTZEN, 2002, 2006; STEFFEN; CRUTZEN; MCNEILL, 2007; STEFFEN *et al*., 2011, 2015). In this sense, the scientific debate revolves around understanding the characteristics, magnitude, dimensions, and scope of the observed (and projected) transformations, to establish the "balance of forces" between two competing antagonistic powers.

Based on such general problems, this article aims to develop a critical analysis of some of the main approaches and concepts found in the scientific literature on the Anthropocene. More precisely, we seek to investigate how discussions around the concept, originally circumscribed to its geological and biophysical sense, reach new dimensions and mobilize theoretical re-elaborations within the scope of social theory and in interdisciplinary domains of knowledge. In this sense, three analytical categories stand out: the concepts of Society, Nature, and Culture, as well as the relationships conceived around their interactions. Our central question is: how do theoretical-scientific discussions about the Anthropocene collaborate to redefine categories central to understanding modern industrial societies, such as the concepts of Society, Nature, and Culture?

In methodological terms, this study is defined as a literature review article, based on non-systematic bibliographic research (MARCONI; LAKATOS, 2017; MEDEIROS; TOMASI, 2016). We justify the non-systematic nature of the review undertaken based on the originality of the debates around the object under analysis, as well as the exponential character associated with the volume of publications on the subject in the past fifteen years (BRONDIZIO *et al*., 2016). In this sense, we privilege a qualitative research approach, recognizing the advantages and limitations arising from such a choice, in aspects such as depth of analysis and absence of statistical representativeness (MARCONI; LAKATOS, 2017).

Regarding the criteria for identifying and selecting references, we start with the pioneering publications of Crutzen (2002) and Crutzen and Stoermer (2000), in addition to the studies carried out by the Anthropocene Working Group (AWG) within the scope of the International Commission on Stratigraphy (ICS). Based on this, we searched for the term "Anthropocene" in the Google Scholar and Scopus databases and selected publications with the greatest impact and relevance, in terms of the number of citations and topicality. In addition, we consider the relevance of the work analyzed for the objectives of this article, especially from the mobilization of the fundamental analytical categories of Society, Nature, and Culture within the scope of social theory and interdisciplinary domains of knowledge.

The article is divided into three sections. In the first part, we present some of the main arguments, perspectives, and dissonant points of view constituting the scientific literature about the definition of a new geological period named Anthropocene, as well as its fundamental characteristics, and the appropriate markers for establishing its starting date. Next, we discuss the theoretical-epistemological assumptions and reverberations present in the most prominent propositions about the concept, particularly from the work of the Anthropocene Working Group (AWG). In the third part, we expand the discussion about the theoretical, cultural, political, social, and epistemological developments involved in the debates about the Anthropocene, highlighting the issues pertinent to the theoretical relationships between Nature, Culture, and Society in the conditions of modernity. In the conclusion, we point out the potentialities identified from the use of the Anthropocene idea, based on the analysis undertaken of the theoretical-scientific debates and the observed capacity of the concept to reverberate profound transformations (and metamorphoses) constitutive of modern industrial societies.

2 SCIENTIFIC CONTROVERSIES ABOUT THE ANTHROPOCENE

The idea that the human species exerts significant changes and impacts on the natural environment, throughout virtually all its evolutionary history, is widely recognized and discussed in the scientific literature. Such recognition of the effects of anthropic actions on terrestrial landscapes, on the composition and diversity of biological species, on the disturbance of biogeochemical and ecological dynamics is seen as a fundamental precursor to the contemporary concept of Anthropocene, based on the intellectual production of authors from the 19th and beginning of the 20th centuries (CRUTZEN, 2002; CRUTZEN; STOERMER, 2000; HAMILTON; GRINEVALD, 2015; LEWIS; MASLIM, 2015; STEFFEN *et al*., 2011; ZALASIEWICZ *et al*., 2018). However, the proposition of a new geological period in the history of planet Earth, characterized by the large-scale performance of humanity as a factor of unprecedented degradation and disturbance, represents a radical breaking point in scientific and intellectual terms (HAMILTON; GRINEVALD, 2015).

The formal recognition of the Anthropocene period as the most recent division on the geological time scale depends on a rigorous process of gathering evidence, establishing measurements and correlations, and, finally, on expressive approval by the community of scientific experts in the fields of geosciences, geology, and associated disciplines. The work undertaken by the Anthropocene Working Group (AWG) in this regard is institutionally linked to the Subcommission on Quaternary Stratigraphy of the International Commission on Stratigraphy (ICS). Thus, the proposal in favour of the official establishment of the geological period of the Anthropocene requires a written, robust, and consistent formulation from the AWG and a critical evaluation in the different institutional instances listed here. If approved by a margin greater than or equal to 60% of the voting members within the scope of the Subcommittee on Quaternary Stratigraphy, the proposal proceeds for consideration by the ICS executive council and the chairs of the sixteen subcommittees that integrate such entity. If approved again by a margin of 60%, ratification is finally required from the executive committee of the International Union of Geological Sciences (IUGS), the highest decision-making agency (FINNEY; EDWARDS, 2016; LEWIS; MASLIM, 2015; TRISCHLER, 2016; ZALASIEWICZ *et al*., 2017, 2018).

We note, therefore, the complexity and scope of the steps related to the decision-making process of scientific controversies and disputes, as is the case with the formal establishment of the Anthropocene. Within this specific issue, some perspectives and points of view stand out, calling into question the usefulness of the scientific definition regarding the Anthropocene, its precision and conceptual rigour, as well as the ideological motivations and/or political interests involved. In this sense, among the proposals in dispute, some questions emerge pointing to the absence of consistent technical criteria, which are indispensable to the consolidated scientific practice of geological dating. With this, some authors assertively ask about the appropriate location of discussions about the Anthropocene in the context of popular culture, to the detriment of serious scientific investigation (AUTIN; HOLBROOK, 2012); the eminently political character inscribed in scientific and intellectual movements that seek to affirm the recognition of the concept; and the anthropocentric dimension that can be identified in the discussions involving the Anthropocene (FINNEY, 2014; FINNEY; EDWARDS, 2016). As we will see, such questions can be resumed and deepened when we consider the epistemological, social, political, and cultural developments of the reported disputes (BECK, 1992, 1997, 2018; CHAKRABARTY, 2009, 2018; LATOUR, 1994, 2012, 2017).

The classificatory and conceptual disputes also permeate the debates established among the defenders of the geological concept of the Anthropocene, particularly around the description of its main characteristics and the definition of a starting date for the period. In their influential bibliographic review on the topic published in the journal Nature, Lewis and Maslim (2015) list nine potential candidates discussed in the scientific literature for characterizing and demarcating the beginning of the Anthropocene. They are: megafauna extinction processes that occurred in different geographic locations throughout human history, between 50,000 to 10,000 years BP (before present[1]); the origin of the practices of agriculture, livestock, and permanent human settlements about 11,000 years BP; the intensification and increase of the area converted to agricultural activities (~8,000 years BP to date); the extensive production of rice crops and domesticated ruminant animals, with the concomitant release of large amounts of methane (CH4) into the atmosphere (~6,500 years BP to date); the formation of soils from specifically anthropogenic actions/pressures (~3,000-500 years BP); the historic process of collision between the European Old World and the New World discovered in the Americas ('Orbis hypothesis'); the socio-political, economic, and technological transformations arising from the Industrial Revolution, from the end of the 18th century in England; the detonation of thousands of nuclear artifacts, as tests, in the context of the Cold War; and the large-scale development and production of polluting and environmentally persistent chemicals (LEWIS; MASLIM, 2015)[2].

Each of these propositions is based on the geological, archaeological, and historical reconstruction of impacts arising from human activities in biogeochemical cycles and planetary ecosystem processes, as well as the observation and analysis of anthropogenic dynamics of exploitation, degradation, and disturbance of the Earth system. Depending on the characterization established, regarding the fundamental

rupture milestones towards a new geological period, different theoretical, cultural, and epistemological implications and developments are possible. In the words of Lewis and Maslim (2015, p. 178), "the event or date chosen as the inception of the Anthropocene will affect the stories people construct about the ongoing development of human societies". In the case of the 'Orbis hypothesis,' defended by such authors as one of the most appropriate candidates, its recognition would imply that colonialism, global trade, and the widespread use of coal started the Anthropocene, with broader repercussions for social issues, such as the unequal distribution of power between human groups, economic growth, the impacts of globalized trade, and modern dependence on fossil fuels (LEWIS; MASLIM, 2015)[3].

3 THE HUMAN SPECIES IN THE ANTHROPOCENE: POWER, DOMINATION AND CONTROL

The original formulations of Crutzen (2002) and Crutzen and Stoermer (2000), which inaugurated contemporary discussions on the Anthropocene, set the beginning of such a period at the advent of the Industrial Revolution in the late 18th century. Admitting that the choice of a specific date to mark the origin of the new geological age is relatively arbitrary, the authors argue that the anthropogenic impacts and effects arising from the transformations that took place amid the Industrial Revolution are global, comprehensive, intensive, profound, and lasting. In this sense, humanity starts to place itself as a force acting on a geological scale, and its capacities to modify the biosphere and the Earth system operate in magnitudes comparable to the great forces of Nature. Just as the consequences of natural phenomena, such as large volcanic eruptions, asteroid impacts, changes in the Earth's orbit, and movements of tectonic plates, can result in profoundly different environmental conditions for thousands or millions of years (and in many cases, irreversible), human activities in the Anthropocene exert planetary pressures and impacts of a similar order of magnitude (CRUTZEN, 2002; CRUTZEN; STOERMER, 2000; STEFFEN; CRUTZEN; MCNEILL, 2007). According to Crutzen and Stoermer (2000),

> *Considering these and many other major and still growing impacts of human activities on earth and atmosphere, and at all, including global, scales, it seems to us more than appropriate to emphasize the central role of mankind in geology and ecology by proposing to use the term "Anthropocene" for the current geological epoch. The impacts of current human activities will continue over long periods. (p. 17)*

Here we observe the basic interconnection between the strictly scientific sense of the concept of Anthropocene and its broader cultural dimensions. Far from signifying a problematic and undesirable derivation, the mutual dependence between the spheres of scientific activity, political action, and cultural representation constitutes fundamental data that characterizes the discussions on the theme. As Beck (1992, 1997) observes, regarding the process of reflexive modernization of industrial societies, the spheres of action of politics, science, and society start to be influenced indelibly, to the point that it is no longer possible to establish clear boundaries between each of these spheres. In simplified terms, these are the phenomena of the politicization of science and the scientification of politics, in which new forms of decision and participation are generated from mechanisms of subpolitics (BECK, 1992, 1997, 2018).

In the case of the debates about the Anthropocene, the formal establishment of the new geological period would mark a fundamental change in the theoretical-conceptual, cultural, ontological, and epistemological relationships between the human species and the Earth system (CHAKRABARTY, 2009, 2018; LATOUR, 2014; LEWIS; MASLIM, 2015). This is because, as pointed out above, human activities would be directly recognized as the dominant cause of most contemporary environmental changes, with their impacts and repercussions on the very dynamics of functioning of the planetary biogeochemical, natural, and evolutionary processes. Such a condition would place humanity, in one way or another, as an active and self-conscious agent, responsible for the operation of the support systems of the very possibilities of life (STEFFEN; CRUTZEN; MCNEILL, 2007). A similar perspective is also present in an editorial text published by the journal Nature in 2011, in which it is noted that the official recognition of the Anthropocene would invite

interdisciplinary research in science and encourage an important mentality, not only to fully understand the ongoing transformations but also act to control them. Thus, "the first step is to recognize, as the term Anthropocene invites us to do, that we [human beings] are in the driver's seat" (NATURE, 2011, p. 254).

According to this perspective, the observation of the speed, magnitude, and intensity of deleterious anthropogenic changes in global environmental conditions results in the need for the human species to assume its position of responsibility before the impacts generated and the possible existing solutions. Hence, three possibilities for social, political, and philosophical responses about the transformations in question arise business-as-usual, in which the economic system and social institutions continue to operate according to the same fundamental dynamics that originated the Anthropocene period; mitigation, an approach based on the recognition of growing risks and threats, which proposes that human societies should act to reduce their intensive pressures on the Earth system; and geoengineering, which brings together proposals for the active intervention of the human species on the biophysical, chemical, and ecological processes of the planet, to reverse, reorient, and control the trends of environmental imbalance and disturbance (ROCKSTRÖM *et al*., 2009; STEFFEN; CRUTZEN; MCNEILL, 2007; STEFFEN *et al*., 2011, 2015).

Regarding geoengineering options, we note that this is a highly controversial debate full of ethical, social, political, legal, and normative questions (CRUTZEN, 2002, 2006; STEFFEN; CRUTZEN; MCNEILL, 2007; VAUGHAN; LENTON, 2011). This is because such discussions involve broad and deep considerations about the relationships established between human societies and the natural environment, in theoretical, cultural, and epistemological terms. Taking as an example the issue of climate change and global warming caused by anthropic actions, we find geoengineering propositions that suggest the possibility of large-scale technical/technological interventions in the planetary climate system, to fight and reverse the ongoing harmful changes (CRUTZEN, 2006; VAUGHAN; LENTON, 2011).

This attitude of optimism and confidence in the ability of the human species to use its creativity, scientific knowledge, and technological innovations to overcome barriers, limitations, and imbalances arising from nature is synthesized, in cultural terms, in the defence of the idea of a "Good Anthropocene". According to this conception, even in the face of the profound global environmental changes that exist, human systems are prepared to adapt and even thrive on the hottest and least bio-diverse planet that we, as humanity, are building. "Indeed, the history of human civilization might be characterized as a history of transgressing natural limits and thriving" (ELLIS, 2011, p. 42). In this sense, the potential to simultaneously mitigate climate change, preserve nature, and alleviate basic material needs globally lies with the socioeconomic processes and technological capabilities of the human species as a whole (ASAFU-ADJAYE, 2015; ELLIS, 2011, 2015).

4 SOCIAL THEORY AND ENVIRONMENT: CRITICAL PERSPECTIVES ON THE ANTHROPOCENE

As we have highlighted, discussions about the concept of Anthropocene assume developments that extend far beyond controversies and strictly scientific debates, involving central aspects related to the cultural, social, philosophical, and political dimensions of modern societies. Based on the propositions established by Crutzen (2002) and Crutzen and Stoermer (2000), the theme aroused increasing interest and participation, both from the academic community associated with the areas of social sciences and humanities and from the wider lay public, by multiple social media (BAUER; ELLIS, 2018; CHAKRABARTY, 2018; LATOUR, 2014, 2017; TRISCHLER, 2016). These are different spheres of definition and meaning, which are inextricably related, making it very difficult to try to isolate the contributions, references, and conceptualizations specific to each of these theoretical-epistemological fields (BECK, 1992, 1997, 2018; LEWIS; MASLIM, 2015; TRISCHLER, 2016). The Anthropocene Working Group (AWG) itself, responsible for the official proposal of the geological concept, is composed of archaeologists, historians, geographers, and even a lawyer (ZALASIEWICZ *et al*., 2018).

In the scope of the social sciences and humanities, the idea of Anthropocene has received criticism from the broadest and most diversified trends, as well as supporters and followers. In the words of Moore (2016), despite its weaknesses and gaps, the concept of Anthropocene is "the most influential concept in environmental studies over the past decade" (MOORE, 2016, p. 2). In terms of critical perspectives, we can illustrate the wealth of theoretical and conceptual positions from the myriad of nomenclatures suggested as alternatives: instead of Anthropocene, we have propositions such as Capitalocene, Plantationocene, Econocene, Carbocene, Thantocene, Chthulucene, Technocene, Manthropocene, among many others[4]. Within the scope of this article, we direct our attention to just a few of these theoretical contributions present in discussions about the concept, especially those regarding the relationships conceived between Nature (Environment) and Society (Culture) in the conditions of modernity.

The first point of criticism that we would like to highlight refers to the predominant tendency, among the main formulations of the Anthropocene, to consider "humanity" acting as a single, cohesive, and homogeneous agent. This is the main argument supported by Malm and Hornborg (2014), in contrast to the standard narrative that interprets human activities and their impacts on the Earth system from the general category of the human species. Such a discursive movement, according to the authors, proves to be analytically flawed and tends to lead discussions towards mystification and political paralysis. This is because the consideration of global environmental changes, particularly climate change, under the bias of "humanity" as a category of explanation, hides fundamental intraspecific inequalities while naturalizing eminently social, historical, economic, and political processes. "Realising that climate change is 'anthropogenic' is really to appreciate that it is sociogenic" (MALM; HORNBORG, 2014, p. 66, italics from authors). Thus, important questions related to categories of analysis such as power, culture, capital, social classes, inequality, and mode of production comprise a first-rate explanatory axis (BAUER; ELLIS, 2018; CHAKRABARTY, 2018; HARAWAY, 2015, 2016; LATOUR, 2014; MALM; HORNBORG, 2014).

Such critical positioning is at the base of the proposition of the term Capitalocene, in contrast to the formulations in favour of the recognition of the Anthropocene. Thus, according to this perspective, an accurate understanding of the new geological period in which we live requires recognizing the decisive factors that gave rise to, sustain, and promote the profound ecological and environmental transformations observed on the planet and in the forms of life that inhabit it. According to Moore (2015, 2016), one must locate, in the logic of the formation, structuring, and functioning of capitalism, the roots of contemporary systemic crises, both social and ecological. Under this key, capitalism can be understood as a way of organizing nature as a whole, configuring itself according to a world ecology that integrates capital accumulation, the search for power, and the co-production of nature in successive historical formations. In this sense, the widespread notion of Anthropocene raises central questions that it is not able to answer (MOORE, 2016).

Another critical point concerns the identification of a markedly anthropocentric character in the debates about the Anthropocene. In the opinion of some authors, this anthropocentric stance is expressed, for example, in the unprecedented suggestion to characterize and officially name a specific geological period based on the activities performed by a single biological species, such species being precisely ours (FINNEY, 2014; FINNEY; EDWARDS, 2016). Among the specialities of the social sciences and humanities, perspectives aligned to the so-called neo-materialism point out that the views related to the concept of Anthropocene, both optimistic and pessimistic, operate from the conventional modernist belief of separation between humans (and their cultural domain) and the natural material world. Thus, as soon as we start talking about the human species as a 'geological actor' that is leading us into a new 'Human Age,' "we begin to overestimate human power and agency, tending towards a celebratory stance even when the intent is to be critical" (LECAIN, 2015, p. 4). According to LeCain (2015), therefore, the concept of Anthropocene suffers from a serious flaw, namely: its fundamentally anthropocentric focus of the biogeochemical phenomena that it proposes to register[5].

This leads us to the last point that we would like to address, concerning the cultural, political, epistemological, and ontological developments inherent to debates about the Anthropocene. It is precisely the fundamental modern distinction between the fields of Nature, on the one hand, and Society (Culture), on the other. Latour (1994, 2012, 2017) can be pointed out as one of the contemporary social theorists who best synthesized the analyses on such a historical process of cultural, intellectual, and epistemological split, as well as their breaking points and philosophical and social implications. In his study, the question of agency appears as a privileged topic of investigation, putting many of the central assumptions and axioms that constitute hegemonic modes of thought in modern Western societies on hold. Among these basic assumptions, the author draws attention to the progressive breakdown of a "scientific worldview" that established the existence of an objective material reality consisting of mere physical, passive, and inanimate objects (LATOUR, 1994, 2012, 2017).

In the context of discussions on the new geological period of the Anthropocene, Bruno Latour's contributions lead us to broad, deep, and fundamental reflections. Addressing specifically the problem of agency in the Anthropocene, Latour (2014) observes that it is impossible to understand the current global environmental transformations and changes from a distant and objective position as if it were only dealing with 'information' coming from the material natural world and from the sciences responsible for investigating it. "There is no distant place anymore. And along with distance, objectivity is gone as well; or at least, an older notion of objectivity that was unable to take into account the active subject of history" (LATOUR, 2014, p. 2). Thus, one must recognize the unfolding of a process of redistribution of the roles of subject and agency in the conditions of modernity under the Anthropocene, in which the human species is displaced from its dreams of control, power, and domination over the wild world of nature. Under the threat of global warming, we can notice the occurrence of a curious inversion in the Western philosophical perspective: human history becomes paralyzed and frozen, while natural history is taking a frantic and fast pace (LATOUR, 2014, 2017).

Chakrabarty (2009, 2018), in contributions that have become central to the discussions on the Anthropocene among the social sciences and humanities, reinforces the reading that the new geological period is marked by the collapse of the old humanist distinction established between natural history and human history. In this sense, the challenge imposed by this new socio-historical configuration lies in integrating, within the same theoretical, cultural, epistemological, and ontological framework, two widely different registers: the way of thinking based on human history (World History), with its categories such as empires, colonies, classes, institutions, nations; and the way of thinking situated on the scale of planetary geological and biogeochemical processes (Earth History). In other words, "the geologic now of the Anthropocene has become entangled with the now of human history" (CHAKRABARTY, 2009, p. 212). For social theorists and humanists living in this new geo-historical period, issues involving the history of volcanoes, mountains, oceans, and tectonic plates have become as routine, in the exercise of critical and analytical thinking, as questions about global capital and the necessary inequalities of the world it produced (CHAKRABARTY, 2018; LATOUR, 2014).

5 FINAL CONSIDERATIONS

The idea of Anthropocene, more than just a concept restricted to the scientific community of experts in geosciences, is part of a broad space for discussion and reflection, which takes as its main object of analysis the intense anthropogenic impacts on the dynamics of planetary ecosystem regulation and functioning. Thus, we note the predominance of significant conceptual controversies, classificatory disputes, different positions and political questions about the terms, definitions, and characteristics associated with the recognition of a new geological period in the history of planet Earth. In such debates, the technical, scientific, political, cultural, and normative dimensions are deeply entangled and interconnected, in the wake of more comprehensive socio-historical processes, which concern the configurations of modernity in Western industrial societies (BECK, 1992, 1997, 2018; HARAWAY, 2015, 2016; LATOUR, 1994, 2012, 2017; MOORE, 2015, 2016).

Anyway, the observed reality concerns the registration of the multiple deleterious effects arising from human activities in the most varied dimensions and phenomena of the biosphere and the Earth system (ARTAXO, 2014; CRUTZEN, 2002; CRUTZEN; STOERMER, 2000; ROCKSTRÖM *et al*., 2009; STEFFEN *et al*., 2011, 2015; ZALASIEWICZ *et al*., 2017, 2018). In most of these parameters, human pressures and impacts have intensified, as we collectively advance within the scope of the Anthropocene. In this regard, the agency issue and the resulting theoretical, cultural, and political developments are of decisive importance. Whether from propositions that recognize the human species acting as a cohesive geological force in interaction with the Earth system, or from criticism to a unifying vision of humanity that disregards inequalities in power and capital, or even under indications that the essential political task is to distribute the agency in the most different and broad ways possible, what is observed is a process of basic restructuring of the dynamics of social ordering in the Anthropocene. This is a historical moment in which old conceptual categories and conventional modes of thought and cognition no longer meet the pressing needs of a time marked by urgency and acceleration.

Thus, we conclude that the notion of Anthropocene is presented as a driving idea6 with enormous potential for the efforts to understand, analyze, and act in the 21st century's historical reality. At the same time that it seeks to constitute a rigorous scientific concept, the idea of Anthropocene mobilizes a wide range of cultural, political, ecological, economic, and technological transformations, changes, and metamorphoses responsible for configuring the emergence of new socio-historical conditions and possibilities. In proposing, in his latest work, the notion of "metamorphosis" as an explanatory key to contemporary processes of social change, Beck (2018) indicates that "metamorphosis implies a much more radical transformation, in which the old certainties of modern society are disappearing and something entirely new emerges" (BECK, 2018, p. 11). Before such a political and existential condition, the author recalls, it is necessary to redefine our way of being in the world, of thinking about the world, of imagining and doing politics, recognizing the profound consequences and implications of living in the era of side effects.

In theoretical-methodological terms, this means locating the discussions and debates about the Anthropocene in an eminently broad and plural field of conceptual possibilities and definition relationships. The different ways of conceiving the relationships between Nature, Society, and Culture mobilized by the driving idea of Anthropocene thus require different movements for redefining the interactions between agency, structure, and social change in the socio-historical context of modern industrial societies. Analytical categories dear to the intellectual traditions consolidated in social theory, such as class, nation, and state, lose explanatory power before new theoretical and practical references, such as the "world," the "planet," and "humanity". As we have noted, the notion of Anthropocene represents a decisive contribution to the task of navigating the stormy seas of the profound changes and transformations of a world in metamorphosis.

ACKNOWLEDGMENTS

The authors thank Capes (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior), Fapesp (Fundação de Amparo à Pesquisa do Estado de São Paulo – process n.19/14867-2), for the financial support to our research projects, and Espaço da Escrita – Pró-Reitoria de Pesquisa – Unicamp, for the language services provided. Also, we would like to thank the reviewers for their thoughtful comments and suggestions made about our manuscript.

NOTES

1. Before present (BP) – indicates the systematization of the time count for geological events, in which the 'present' is defined as the 1950 calendar date. Cf. Lewis and Maslim (2015).

2. Cf. Bauer and Ellis (2018), Ellis (2011), Ruddiman (2003, 2013), Steffen, Crutzen, and McNeill (2007), Steffen et al. (2011, 2015), Trischler (2016), Waters et al. (2016), and Zalasiewicz et al. (2017, 2018).

3. Cf. LeCain (2015), Malm and Hornborg (2014), and Moore (2015, 2016).

4. Cf. Bauer and Ellis (2018), Chakrabarty (2018), Haraway (2015, 2016), Latour (2017), LeCain (2015), Malm and Hornborg (2014), and Moore (2015, 2016).

5. The debate regarding human performance in the configuration of the landscape and the biodiversity of different locations has multiple perspectives and different analytical axes. In this regard, we must mention the rich contribution provided by Archaeology in the discussion of such historical processes of fundamental interconnection between social, cultural, biological, and ecological dimensions. There is a whole field of research and analysis, called Historical Ecology, which has recently turned to the consideration of similar problems, from a very innovative and thought-provoking perspective. Cf. Balée (2006, 2008), Neves and Petersen (2006), Rival (2006), and Roosevelt (2013).

6. By "driving idea", we mean the category of analytical concepts that unfold in multiple perspectives, approaches, and theoretical orientations, often conflicting with each other. At the same time, they are concepts that imply normative, ethical, and political reference points that are intended to be common and consensual. The idea of sustainable development can be considered a paradigmatic example of a similar conceptual category (FERREIRA, 2006; VEIGA, 2008). In addition, political-normative concepts such as "freedom," "democracy," and "justice" can also be understood from this perspective (MEADOWCROFT, 2007).

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Disputas classificatórias e controvérsias científicas: sociedade, natureza e cultura no Antropoceno

Classificatory disputes and scientific controversies: society, nature and culture in the Anthropocene

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doi:10.18472/SustDeb.v12n2.2021.34395

Received: 28/09/2020
Accepted: 24/03/2021

ARTICLE – VARIA

RESUMO

De maneira geral, a ideia de Antropoceno faz referência ao conjunto de transformações sócio-históricas, ecológicas, econômicas e tecnológicas responsáveis por configurar uma nova etapa de regulação e evolução do sistema geológico planetário. A partir de sua proposição original nos anos 2000, essa noção ganhou repercussão cada vez maior, mobilizando posicionamentos díspares em múltiplos campos do conhecimento científico. Este artigo tem como objetivo desenvolver análise crítica a respeito de algumas das principais concepções encontradas em tais debates, a partir da mobilização de três categorias analíticas fundamentais: os conceitos de Sociedade, Natureza e Cultura. Em termos metodológicos, trata-se de artigo de revisão da literatura, a partir de pesquisa bibliográfica de caráter qualitativo e não sistemático. A análise empreendida indica como as diferentes abordagens mobilizadas pela ideia-força de Antropoceno implicam movimentos teóricos de redefinição das relações entre agência, estrutura e mudança social no contexto histórico das sociedades industriais modernas.

Palavras-chave: Antropoceno. Sustentabilidade. Teoria Social. Mudanças Climáticas.

ABSTRACT

In general, the idea of Anthropocene makes reference to the set of socio-historical, ecological, economic, and technological transformations responsible for configuring a new stage of regulation and evolution of the planetary geological system. From its original proposition in the 2000s, this notion gained increasing repercussion, mobilizing different positions in multiple fields of scientific knowledge. This article aims to develop a critical analysis of some of the main concepts found in such debates, from the mobilization of three fundamental analytical categories: the concepts of Society, Nature, and Culture. In methodological terms, this is a literature review article, based on a qualitative and non-systematic bibliographic research. The analysis undertaken here indicates how the different approaches mobilized by the driving idea of Anthropocene result in theoretical movements that redefine the relationships between agency, structure, and social change in the historical context of modern industrial societies.

Keywords: Anthropocene. Sustainability. Social Theory. Climate Change.

1 INTRODUÇÃO

Desde sua apresentação no começo dos anos 2000, a ideia de Antropoceno ganhou enorme repercussão e popularidade nos fóruns de debate científico, bem como nos espaços culturais e midiáticos de comunicação social (CRUTZEN, 2002; CRUTZEN; STOERMER, 2000; MONASTERSKY, 2015; STEFFEN *et al*., 2011, 2015; TRISCHLER, 2016). Em termos acadêmicos, tal importância se expressa, por exemplo, no lançamento e publicação de periódicos científicos exclusivamente dedicados ao tema: "*The Anthropocene*", "*Elementa: Science of the Anthropocene*" e "*The Anthropocene Review*". Além disso, artistas e arquitetos têm respondido às implicações dessa discussão em sua prática profissional, poetas e escritores traduzem seus conceitos em produções literárias e convidam acadêmicos e ecocríticos a refletir sobre semelhantes práticas de tradução cultural (LEWIS; MASLIM, 2015; TRISCHLER, 2016).

De maneira geral, a ideia de Antropoceno faz referência ao conjunto de transformações sociais, históricas, ecológicas, econômicas, políticas, culturais e tecnológicas responsáveis por configurar uma nova etapa de regulação e evolução do sistema geológico planetário. Sua premissa fundamental está embasada em observações, medições, estudos de tendências e registros que indicam a ocorrência e intensificação de múltiplos processos de desequilíbrio, exploração e perturbação nas dinâmicas de regulação ecossistêmica nas mais diferentes escalas planetárias (ARTAXO, 2014; CRUTZEN, 2002; CRUTZEN; STOERMER, 2000; ROCKSTRÖM *et al*., 2009; STEFFEN *et al*., 2011, 2015; ZALASIEWICZ *et al.*, 2017, 2018). Em contraponto ao período do Holoceno, a espécie humana passaria a se colocar como força atuante em escala geológica, a partir de suas atividades e interações intensivas com o ambiente biofísico. Nesse sentido, as ações antrópicas tornam-se tão amplas e profundas que assumem características de rivalidade com relação às grandes forças da natureza e pressionam o sistema terrestre em direção ao incerto e desconhecido (STEFFEN; CRUTZEN; MCNEILL, 2007).

Entendido dessa maneira, o debate em torno de uma Era dos Humanos ("*Age of Humans*") parece operar a partir da cisão estabelecida entre sociedade (ou cultura) e natureza (ou ambiente biofísico) (CHAKRABARTY, 2009, 2018; LATOUR, 1994, 2012, 2014, 2017; LEWIS; MASLIM, 2015; TRISCHLER, 2016). Em outros termos, é como se a capacidade de organização e atividade humana assumisse posição de independência com relação às limitações anteriormente estabelecidas pelas dimensões físicas, biológicas e naturais de estruturação da existência humana. A partir de um poder de manipulação e transformação cada vez mais especializado e concentrado, a humanidade rearticula seu lugar na paisagem da evolução das espécies, colocando-se muitas vezes em uma posição de dominação e/ou controle das forças, processos e fenômenos tipicamente caracterizados como naturais (CRUTZEN, 2002, 2006; STEFFEN; CRUTZEN; MCNEILL, 2007; STEFFEN *et al*., 2011, 2015). Nesse sentido, o debate científico gira em torno de compreender as características, magnitude, dimensões e alcance das transformações observadas (e projetadas), de modo a estabelecer o "equilíbrio de forças" entre duas potências antagônicas em embate.

A partir de tais problemáticas gerais, o objetivo do artigo centra-se em desenvolver análise crítica a respeito de algumas das principais abordagens e concepções encontradas na literatura científica sobre o Antropoceno. De modo mais preciso, buscamos investigar a maneira pela qual as discussões em torno do conceito, originalmente circunscritas ao seu sentido geológico e biofísico, alcançam novas dimensões e mobilizam reelaborações teóricas no escopo da teoria social e em domínios interdisciplinares de conhecimento. Nesse sentido, três categorias analíticas destacam-se: os conceitos de Sociedade, Natureza e Cultura, bem como as relações concebidas em torno de suas interações. Em forma de indagação, temos que nossa questão central é: como as discussões teórico-científicas sobre o Antropoceno colaboram para redefinir categorias centrais à compreensão das sociedades industriais modernas, como os conceitos de Sociedade, Natureza e Cultura?

Em termos metodológicos, este trabalho define-se como artigo de revisão da literatura, a partir de pesquisa bibliográfica de caráter não sistemático (MARCONI; LAKATOS, 2017; MEDEIROS; TOMASI, 2016). Justificamos o caráter não sistemático da revisão empreendida a partir da originalidade dos debates em torno do objeto em análise, bem como do caráter exponencial associado ao volume de publicações sobre o tema nos últimos 15 anos (BRONDIZIO *et al*., 2016). Nesse sentido, privilegiamos uma abordagem qualitativa de investigação, reconhecendo as vantagens e limitações advindas de tal escolha, em aspectos como profundidade da análise e ausência de representatividade estatística (MARCONI; LAKATOS, 2017).

Com relação aos critérios de identificação e seleção das referências bibliográficas, partimos em primeiro lugar das publicações pioneiras de Crutzen e *Stoermer* (2000) e Crutzen (2002), além dos trabalhos realizados pelo *Anthropocene Working Group* (AWG) no âmbito da Comissão Internacional em Estratigrafia (*International Commission on Stratigraphy* – ICS). A partir disso, buscamos pelo termo "*Anthropocene*" nas bases de dados Google Scholar e Scopus e selecionamos publicações de maior impacto e relevância, em termos de número de citações e atualidade. Além disso, consideramos a pertinência do trabalho analisado em relação aos objetivos do presente artigo, em especial a partir da mobilização das categorias analíticas fundamentais de Sociedade, Natureza e Cultura no âmbito da teoria social e domínios interdisciplinares de conhecimento.

O artigo está dividido em três seções. Na primeira parte, apresentamos alguns dos principais argumentos, perspectivas e pontos de vista dissonantes constitutivos da literatura científica acerca da definição de um novo período geológico nomeado de Antropoceno, suas características fundamentais e os marcadores apropriados para o estabelecimento da sua data de início. Em seguida, discutimos os pressupostos e reverberações teórico-epistemológicas presentes nas proposições de maior destaque acerca do conceito, particularmente a partir do trabalho do *Anthropocene Working Group* (AWG). Na terceira parte, ampliamos a discussão acerca dos desdobramentos teóricos, culturais, políticos, sociais e epistemológicos implicados nos debates acerca do Antropoceno, com ênfase para as questões pertinentes às relações teóricas entre Natureza, Cultura e Sociedade nas condições da modernidade. Na conclusão, apontamos as potencialidades identificadas a partir da utilização da ideia de Antropoceno, com base na análise empreendida dos debates teórico-científicos e na capacidade observada do conceito em reverberar profundas transformações (e metamorfoses) constitutivas das sociedades industriais modernas.

2 CONTROVÉRSIAS CIENTÍFICAS ACERCA DO ANTROPOCENO

A ideia de que a espécie humana exerce alterações e impactos significativos no ambiente natural, ao longo de praticamente toda sua história evolutiva, é bastante reconhecida e discutida na literatura científica. Tal reconhecimento dos efeitos das ações antrópicas nas paisagens terrestres, na composição e diversidade de espécies biológicas, na perturbação de dinâmicas biogeoquímicas e ecológicas é tido como precursor fundamental ao conceito contemporâneo de Antropoceno, a partir da produção intelectual de autores localizados no século XIX e começo do século XX (CRUTZEN, 2002; CRUTZEN; STOERMER, 2000; HAMILTON; GRINEVALD, 2015; LEWIS; MASLIM, 2015; STEFFEN *et al*., 2011; ZALASIEWICZ *et al*., 2018). No entanto, a proposição de um novo período geológico na história

do planeta Terra, caracterizado pela atuação em larga escala da humanidade como fator de degradação e perturbação sem precedentes, representa um ponto de ruptura radical em termos científicos e intelectuais (HAMILTON; GRINEVALD, 2015).

O reconhecimento formal do período do Antropoceno, como divisão mais recente na escala de tempo geológica, depende de um rigoroso processo de reunião de evidências, estabelecimento de medições e correlações e, finalmente, aprovação expressiva por parte da comunidade de especialistas científicos nos domínios das geociências, geologia e disciplinas associadas. O trabalho empreendido pelo Anthropocene Working Group (AWG) a esse respeito está vinculado institucionalmente à Subcommission on Quaternary Stratigraphy da Comissão Internacional em Estratigrafia (International Commission on Stratigraphy – ICS). Assim, a proposta em favor do estabelecimento oficial do período geológico do Antropoceno necessita de uma formulação escrita, robusta e consistente a partir do AWG e da avaliação crítica nas diferentes instâncias institucionais aqui elencadas. Se aprovada por uma margem maior ou igual a 60% dos membros votantes no âmbito da Subcomissão em Estratigrafia Quaternária, a proposta segue para consideração do conselho executivo da ICS e os presidentes (chairs) das 16 subcomissões que integram tal entidade. Caso seja aprovada novamente por uma margem de 60%, é exigida finalmente a ratificação por parte do comitê executivo da International Union of Geological Sciences (IUGS), órgão máximo de deliberação (FINNEY; EDWARDS, 2016; LEWIS; MASLIM, 2015; TRISCHLER, 2016; ZALASIEWICZ *et al*., 2017, 2018).

Notamos, assim, a complexidade e abrangência das etapas relacionadas ao processo decisório de controvérsias e contendas científicas, como é o caso do estabelecimento formal do Antropoceno. No escopo dessa questão específica, destacam-se alguns posicionamentos e pontos de vista que colocam em questão a utilidade da definição científica em relação ao Antropoceno, sua precisão e rigor conceitual, bem como as motivações ideológicas e/ou interesses políticos implicados.

Nesse sentido, podem ser encontrados questionamentos que apontam para a ausência de critérios técnicos consistentes, indispensáveis à prática científica consolidada de datação geológica, entre as proposições em disputa. Com isso, alguns autores indagam assertivamente acerca da apropriada localização das discussões sobre o Antropoceno no âmbito da cultura pop, em detrimento da investigação científica séria (AUTIN; HOLBROOK, 2012); do caráter eminentemente político inscrito nos movimentos científicos e intelectuais que buscam afirmar o reconhecimento do conceito; e da dimensão antropocêntrica que pode ser identificada nas discussões envolvendo o Antropoceno (FINNEY, 2014; FINNEY; EDWARDS, 2016). Como veremos, tais questionamentos podem ser retomados e aprofundados ao considerarmos os desdobramentos epistemológicos, sociais, políticos e culturais dos embates assinalados (BECK, 1992, 1997, 2018; CHAKRABARTY, 2009, 2018; LATOUR, 1994, 2012, 2017).

As disputas classificatórias e conceituais também permeiam os debates estabelecidos entre os defensores do conceito geológico do Antropoceno, particularmente em torno da descrição de suas principais características e da definição de uma data de início para o período. Em sua influente revisão bibliográfica sobre o tema publicada na revista Nature, Lewis e Maslim (2015) elencam nove potenciais candidatos discutidos na literatura científica para a caracterização e demarcação do início do Antropoceno. São eles: processos de extinção da megafauna ocorridos em diferentes localizações geográficas ao longo da história humana, entre 50.000 a 10.000 anos BP (before present1); a origem das práticas de agricultura, pecuária e assentamentos humanos permanentes há aproximadamente 11.000 anos BP; a intensificação e aumento da área convertida para atividades agropecuárias (~8.000 anos BP até o presente); a produção extensiva de culturas de arroz e de animais ruminantes domesticados, com a liberação concomitante de grandes quantidades de metano (CH4) para a atmosfera (~6.500 anos BP até o presente); a formação de solos a partir de ações/pressões especificamente antropogênicas (~3.000-500 anos BP); o processo histórico de colisão entre o Velho Mundo europeu e o Novo Mundo descoberto nas Américas ('Orbis hypothesis'); as transformações sociopolíticas, econômicas e tecnológicas oriundas da Revolução Industrial, a partir de finais do século XVIII na Inglaterra; a detonação de milhares de artefatos nucleares, em caráter de testes, no contexto da Guerra Fria; e o desenvolvimento e produção em larga escala de substâncias químicas poluentes e ambientalmente persistentes (LEWIS; MASLIM, 2015)[2].

Cada uma dessas proposições baseia-se na reconstrução geológica, arqueológica e histórica de impactos advindos de atividades humanas nos ciclos biogeoquímicos e processos ecossistêmicos planetários, bem como da observação e análise das dinâmicas antropogênicas de exploração, degradação e perturbação do sistema terrestre. A depender da caracterização estabelecida, a respeito dos marcos de ruptura fundamentais em direção a um novo período geológico, diferentes implicações e desdobramentos teóricos, culturais e epistemológicos são possíveis. Nas palavras de Lewis e Maslim (2015, p.178, tradução nossa), "o evento ou data escolhidos como o começo do Antropoceno afetarão as histórias que as pessoas constroem acerca do desenvolvimento contínuo das sociedades humanas". No caso da "hipótese Orbis", defendida por tais autores como um dos candidatos mais apropriados, seu reconhecimento implicaria afirmar que o colonialismo, o comércio global e o uso difundido de carvão deram início ao Antropoceno, com reverberações mais amplas para questões sociais como a distribuição desigual de poder entre grupos humanos, crescimento econômico, os impactos do comércio globalizado e a dependência moderna de combustíveis fósseis (LEWIS; MASLIM, 2015)[3].

3 A ESPÉCIE HUMANA NO ANTROPOCENO: PODER, DOMINAÇÃO E CONTROLE

As formulações originais de Crutzen e Stoermer (2000) e Crutzen (2002), que inauguraram as discussões contemporâneas sobre o Antropoceno, situam o início de tal período no advento da Revolução Industrial no fim do século XVIII. Admitindo que a escolha de uma data específica para marcar a origem da nova época geológica mostra-se relativamente arbitrária, os autores argumentam que os impactos e efeitos antropogênicos oriundos das transformações ocorridas no bojo da Revolução Industrial apresentam caráter global, abrangente, intensivo, profundo e duradouro.

Nesse sentido, a humanidade passa a se colocar como força atuante em escala geológica e suas capacidades de modificação da biosfera e do sistema terrestre operam em magnitudes comparáveis às grandes forças da natureza. Assim como as consequências de fenômenos naturais, como grandes erupções vulcânicas, impactos de asteroides, mudanças na órbita terrestre e movimentos de placas tectônicas, podem resultar em condições ambientais profundamente diferentes por milhares ou milhões de anos (e em muitos casos, irreversíveis), as atividades da espécie humana no Antropoceno exercem pressões e impactos planetários de semelhante ordem de grandeza (CRUTZEN, 2002; CRUTZEN; STOERMER, 2000; STEFFEN; CRUTZEN; MCNEILL, 2007). De acordo com Crutzen e Stoermer (2000),

> *Considerando esses e muitos outros grandes e crescentes impactos das atividades humanas na terra e atmosfera, e em todas escalas, inclusive global, parece-nos mais do que apropriado enfatizar o papel central da humanidade na geologia e na ecologia, propondo usar o termo "antropoceno" para a época geológica corrente. Os impactos das atuais atividades humanas continuarão por longos períodos de tempo. (p. 17, tradução e grifo nossos).*

Aqui observamos a interconexão basilar entre o sentido estritamente científico do conceito de Antropoceno e suas dimensões culturais mais amplas. Longe de significar uma derivação problemática e indesejável, a mútua dependência entre as esferas da atividade científica, atuação política e representação cultural configura dado fundamental que caracteriza as discussões sobre o tema. Como Beck (1992, 1997) observa, a respeito do processo de modernização reflexiva das sociedades industriais, os âmbitos de atuação da política, ciência e sociedade passam a se influenciar de maneira indelével, a ponto de não ser mais possível estabelecer a separação clara ou delinear fronteiras nítidas entre cada uma dessas esferas. Em termos simplificados, trata-se dos fenômenos da politização da ciência e da cientificação da política, nos quais novas formas de decisão e participação são gestadas a partir de mecanismos da subpolítica (BECK, 1992, 1997, 2018).

No caso dos debates sobre o Antropoceno, o estabelecimento formal da nova época geológica marcaria uma mudança fundamental nas relações teórico-conceituais, culturais, ontológicas e epistemológicas entre a espécie humana e o sistema terrestre (Earth system) (CHAKRABARTY, 2009, 2018; LATOUR, 2014; LEWIS; MASLIM, 2015). Isso porque, como apontado acima, as atividades humanas seriam diretamente reconhecidas como causa dominante de grande parte das alterações ambientais contemporâneas, com seus impactos e repercussões nas próprias dinâmicas de funcionamento dos processos biogeoquímicos, naturais e evolutivos planetários. Tal condição colocaria a humanidade, de uma maneira ou de outra, como um agente ativo e autoconsciente, responsável pela operação dos sistemas de suporte das próprias possibilidades de vida (STEFFEN; CRUTZEN; MCNEILL, 2007).

Semelhante perspectiva também está presente em um texto editorial publicado pela revista Nature em 2011, no qual a publicação observa que o reconhecimento oficial do Antropoceno convidaria à realização de pesquisa interdisciplinar na ciência e encorajaria uma mentalidade importante, não apenas para entender completamente as transformações em curso, mas também para agir no sentido de controlá-las. Assim, "o primeiro passo é reconhecer, como o termo Antropoceno nos convida a fazer, que nós [seres humanos] estamos no banco do motorista" (NATURE, 2011, p. 254, tradução nossa).

De acordo com tal perspectiva, a constatação da velocidade, magnitude e intensidade das alterações antropogênicas deletérias nas condições ambientais globais implica a necessidade de a espécie humana assumir sua posição de responsabilidade diante dos impactos gerados e das possíveis soluções existentes. Surgem daí três possibilidades de respostas sociais, políticas e filosóficas acerca das transformações em pauta: business-as-usual, em que o sistema econômico e instituições sociais permanecem operando segundo as mesmas dinâmicas fundamentais que originaram o período do Antropoceno; mitigação, abordagem que se baseia no reconhecimento dos riscos e ameaças crescentes e propõe que as sociedades humanas atuem no sentido de reduzir suas pressões intensivas sobre o sistema terrestre; e geoengenharia, que reúne proposições no sentido da intervenção ativa da espécie humana sobre os processos biofísicos, químicos e ecológicos do planeta, a fim de reverter, reorientar e controlar as tendências de desequilíbrio e perturbação ambiental (ROCKSTRÖM *et al*., 2009; STEFFEN; CRUTZEN; MCNEILL, 2007; STEFFEN *et al*., 2011, 2015).

Com relação às opções de geoengenharia, notamos que se trata de um debate altamente controverso e repleto de questionamentos éticos, sociais, políticos, jurídicos e normativos (CRUTZEN, 2002, 2006; STEFFEN; CRUTZEN; MCNEILL, 2007; VAUGHAN; LENTON, 2011). Isso se dá, justamente, porque tais discussões envolvem considerações amplas e profundas acerca das relações instituídas entre sociedades humanas e ambiente natural, em termos teóricos, culturais e epistemológicos. Tomando como exemplo a questão das mudanças climáticas e o aquecimento global causado por ações antrópicas, encontramos proposições de geoengenharia que sugerem a possibilidade de intervenções técnicas/tecnológicas em larga escala no sistema climático planetário, a fim de combater e reverter as alterações deletérias em curso (CRUTZEN, 2006; VAUGHAN; LENTON, 2011).

Essa postura de otimismo e confiança na capacidade da espécie humana de utilizar sua criatividade, conhecimento científico e inovações tecnológicas para superar barreiras, limitações e desequilíbrios advindos da natureza é sintetizada, em termos culturais, na defesa da ideia de um "Bom Antropoceno" (Good Anthropocene). Segundo tal concepção, mesmo diante das profundas mudanças ambientais globais existentes, os sistemas humanos estão preparados para se adaptar e mesmo prosperar no planeta mais quente e menos biodiverso que nós, enquanto humanidade, estamos construindo. "De fato, a história da civilização humana pode ser caracterizada como uma história de transgressão de limites naturais e prosperidade" (ELLIS, 2011, p. 42, tradução nossa). Nesse sentido, o potencial de, ao mesmo tempo, mitigar as mudanças climáticas, preservar a natureza e aliviar necessidades materiais básicas globalmente cabe aos processos socioeconômicos e capacidades tecnológicas da espécie humana como um todo (ASAFU-ADJAYE, 2015; ELLIS, 2011, 2015).

4 TEORIA SOCIAL E AMBIENTE: PERSPECTIVAS CRÍTICAS AO ANTROPOCENO

Como destacamos, as discussões acerca do conceito de Antropoceno assumem desdobramentos que se estendem muito além das controvérsias e debates estritamente científicos, envolvendo aspectos centrais relativos às dimensões culturais, sociais, filosóficas e políticas das sociedades modernas. A partir das proposições estabelecidas por Crutzen (2002) e Crutzen e Stoermer (2000), o tema despertou interesse e participação cada vez maiores, tanto da comunidade acadêmica associada às áreas das ciências sociais e humanidades, quanto do público leigo mais amplo, por meio de múltiplos meios de comunicação social (BAUER; ELLIS, 2018; CHAKRABARTY, 2018; LATOUR, 2014, 2017; TRISCHLER, 2016). Trata-se de diferentes esferas de definição e significado, que se relacionam de modo inextricável, tornando muito difícil a tentativa de isolar as contribuições, referências e conceptualizações próprias a cada um desses campos teórico-epistemológicos (BECK, 1992, 1997, 2018; LEWIS; MASLIM, 2015; TRISCHLER, 2016). O próprio Anthropocene Working Group (AWG), responsável pela proposta oficial do conceito geológico, é composto por arqueólogos, historiadores, geógrafos e mesmo um advogado (ZALASIEWICZ *et al*., 2018).

No âmbito das ciências sociais e humanidades, a ideia de Antropoceno tem recebido críticas das vertentes mais amplas e diversificadas, bem como apoiadores e adeptos. Nas palavras de Moore (2016), apesar de suas fragilidades e lacunas, o conceito de Antropoceno é "o conceito mais influente em estudos ambientais da última década" (MOORE, 2016, p. 2, tradução nossa). Em termos de perspectivas críticas, podemos ilustrar a riqueza de posicionamentos teóricos e conceituais a partir da miríade de nomenclaturas sugeridas como alternativas: em lugar do Anthropocene, temos proposições como Capitalocene, Plantationocene, Econocene, Carbocene, Thantocene, Chthulucene, Technocene, Manthropocene, entre muitas outras4. No escopo do presente artigo, direcionamos nossa atenção para apenas algumas dessas contribuições teóricas presentes nas discussões sobre o conceito, em especial aquelas pertinentes às relações concebidas entre Natureza (ambiente) e Sociedade (Cultura) nas condições da modernidade.

O primeiro ponto de crítica que gostaríamos de destacar refere-se à tendência predominante, entre as principais formulações do Antropoceno, de considerar a "humanidade" atuando como um agente único, coeso e homogêneo. Esse é o argumento principal sustentado por Malm e Hornborg (2014), em contraposição à narrativa-padrão que interpreta as atividades humanas e seus impactos no sistema terrestre a partir da categoria geral da espécie humana. Semelhante movimento discursivo, segundo os autores, demonstra-se analiticamente falho e tende a conduzir os debates em direção à mistificação e paralisia política. Isso porque a consideração das mudanças ambientais globais, particularmente das mudanças climáticas, sob o viés da "humanidade" como categoria de explicação, oculta desigualdades intraespecíficas fundamentais, ao mesmo tempo que naturaliza processos eminentemente sociais, históricos, econômicos e políticos. "Reconhecer que a mudança climática é 'antropogênica' é realmente apreciar que ela é sociogênica [sociogenic]" (MALM; HORNBORG, 2014, p. 66, tradução nossa, grifos do autor). Assim, importantes questões relacionadas a categorias de análise, como poder, cultura, capital, classes sociais, desigualdade e modo de produção, compõem eixo explicativo de primeira grandeza (BAUER; ELLIS, 2018; CHAKRABARTY, 2018; HARAWAY, 2015, 2016; LATOUR, 2014; MALM; HORNBORG, 2014).

Tal posicionamento crítico está na base da proposição do termo Capitaloceno, em contraponto às formulações em favor do reconhecimento do Antropoceno. Assim, segundo essa perspectiva, a compreensão acurada do novo período geológico em que vivemos exige que se reconheçam os fatores decisivos que deram origem, sustentam e promovem as profundas transformações ecológicas e ambientais observadas no planeta e nas formas de vida que o habitam. De acordo com Moore (2015, 2016), é preciso localizar, nas lógicas de formação, estruturação e funcionamento do capitalismo, as raízes das crises sistêmicas contemporâneas, tanto sociais como ecológicas. Sob essa chave, o capitalismo pode ser entendido como uma maneira de organizar a natureza como um todo, configurando-se segundo uma ecologia-do-mundo (world-ecology) que integra a acumulação de capital, a busca por poder e a coprodução da natureza em formações históricas sucessivas. Nesse sentido, a noção difundida de Antropoceno lança questões centrais que não é capaz de responder (MOORE, 2016).

Outro apontamento crítico, relevante de se destacar, diz respeito à identificação de um caráter marcadamente antropocêntrico nos debates sobre o Antropoceno. No entendimento de alguns autores, essa postura antropocêntrica expressa-se, por exemplo, na sugestão inédita de caracterizar e nomear oficialmente um período geológico específico com base nas atividades desempenhadas por uma única espécie biológica, sendo tal espécie justamente a nossa (FINNEY, 2014; FINNEY; EDWARDS, 2016). Entre as especialidades das ciências sociais e humanidades, perspectivas alinhadas ao chamado neomaterialismo apontam que as visões relacionadas ao conceito de Antropoceno, tanto as otimistas como as pessimistas, operam a partir da crença modernista convencional de separação entre humanos (e seu domínio cultural) e o mundo material natural. Desse modo, tão logo comecemos a falar da espécie humana como um "ator geológico" que está nos conduzindo a uma nova "Era dos Humanos", nós "começamos a superestimar poder e agência humanos, tendendo para uma posição de celebração mesmo quando a intenção é a de sermos críticos" (LECAIN, 2015, p. 4, tradução nossa). Segundo LeCain (2015), portanto, o conceito de Antropoceno sofre de uma falha grave, a saber: seu enfoque fundamentalmente antropocêntrico dos fenômenos biogeoquímicos que se propõe a registrar[5].

Isso nos conduz ao último ponto que gostaríamos de abordar, em relação aos desdobramentos culturais, políticos, epistemológicos e ontológicos inerentes aos debates sobre o Antropoceno. Trata-se, precisamente, da distinção moderna fundamental entre os campos da Natureza, de um lado, e da Sociedade (Cultura), de outro. Latour (1994, 2012, 2017) pode ser apontado como um dos teóricos sociais contemporâneos que melhor sintetizou as análises sobre tal processo histórico de cisão cultural, intelectual e epistemológica, bem como seus pontos de ruptura e implicações filosóficas e sociais. Em sua obra, a questão da agência aparece como tema privilegiado de investigação, colocando-se em suspenso muitos dos pressupostos e axiomas centrais que constituem os modos hegemônicos de pensamento nas sociedades ocidentais modernas. Entre esses pressupostos basilares, o autor chama atenção para a progressiva desagregação de uma "visão de mundo científica" que estabelecia a existência de uma realidade material objetiva constituída de meros objetos físicos, passivos e inanimados (LATOUR, 1994, 2012, 2017).

No contexto das discussões sobre o novo período geológico do Antropoceno, as contribuições de Bruno Latour nos conduzem a reflexões amplas, profundas e fundamentais. Abordando especificamente a problemática da agência no Antropoceno, Latour (2014) observa que é impossível compreender as transformações e mudanças ambientais globais atuais a partir de uma posição distante e objetiva, como se tratasse apenas de lidar com "informações" advindas do mundo material natural e das ciências responsáveis por investigá-lo. "Não há mais lugar distante. E junto com a distância, a objetividade também se foi; ou, ao menos, uma antiga noção de objetividade que foi incapaz de levar em consideração o sujeito ativo da história" (LATOUR, 2014, p. 2, tradução nossa).

Desse modo, é preciso reconhecer o desdobramento de um processo de redistribuição dos papéis de sujeito e agência nas condições da modernidade sob o Antropoceno, no qual a espécie humana é deslocada de seus sonhos de controle, poder e domínio sobre o mundo selvagem da natureza. Sob a ameaça do aquecimento global, podemos notar a ocorrência de uma curiosa inversão na perspectiva filosófica ocidental: a história humana torna-se paralisada e congelada, enquanto a história natural está tomando um ritmo frenético e acelerado (LATOUR, 2014, 2017).

Chakrabarty (2009, 2018), em contribuições que se tornaram centrais nos debates sobre o Antropoceno entre as ciências sociais e humanidades, reforça a leitura de que o novo período geológico é marcado pelo colapso da velha distinção humanista estabelecida entre a história natural e a história humana. Nesse sentido, o desafio imposto por essa nova configuração sócio-histórica reside em integrar, no mesmo arcabouço teórico, cultural, epistemológico e ontológico, dois registros amplamente distintos: o modo de pensamento baseado na história mundial humana (world history), com suas categorias como impérios, colônias, classes, instituições, nações, e o modo de pensamento situado na escala dos processos geológicos e biogeoquímicos planetários (Earth history). Em outras palavras, "o presente geológico do Antropoceno tornou-se enredado com o tempo presente da história humana" (CHAKRABARTY, 2009, p. 212, tradução nossa). Para teóricos sociais e humanistas vivendo nesse novo período geo-histórico,

questões envolvendo a história de vulcões, montanhas, oceanos e placas tectônicas tornaram-se tão rotineiras, no exercício do pensamento crítico e analítico, como questões acerca do capital global e as necessárias desigualdades do mundo que ele produziu (CHAKRABARTY, 2018; LATOUR, 2014).

5 CONSIDERAÇÕES FINAIS

A ideia de Antropoceno, mais do que apenas um conceito restrito à comunidade científica de especialistas em geociências, faz parte de um amplo espaço de discussão e reflexão, que toma como objeto de análise principal os intensos impactos antropogênicos nas dinâmicas de regulação e funcionamento dos ecossistemas planetários. Assim, constatamos o predomínio de significativas controvérsias conceituais, disputas classificatórias, posicionamentos díspares e questionamentos políticos a respeito dos termos, definições e características associados ao reconhecimento de um novo período geológico na história do planeta Terra. Em tais debates, as dimensões técnicas, científicas, políticas, culturais e normativas encontram-se emaranhadas e interconectadas de maneira profunda, na esteira de processos sócio-históricos mais abrangentes, que dizem respeito às configurações da modernidade nas sociedades industriais ocidentais (BECK, 1992, 1997, 2018; HARAWAY, 2015, 2016; LATOUR, 1994, 2012, 2017; MOORE, 2015, 2016).

De toda maneira, a realidade observada diz respeito ao registro dos múltiplos efeitos deletérios advindos das atividades humanas nas mais variadas dimensões e fenômenos da biosfera e do sistema terrestre (ARTAXO, 2014; CRUTZEN, 2002; CRUTZEN; STOERMER, 2000; ROCKSTRÖM *et al*., 2009; STEFFEN *et al*., 2011, 2015; ZALASIEWICZ *et al*., 2017, 2018). Em grande parte desses parâmetros, as pressões e impactos humanos têm se intensificado, conforme avançamos coletivamente no âmbito do Antropoceno. Nesse particular, a problemática da agência e os desdobramentos teóricos, culturais e políticos dela decorrentes assumem importância decisiva. Seja a partir de proposições que reconhecem a espécie humana atuando como força geológica coesa em interação com o sistema terrestre, seja a partir da crítica a uma visão unificadora da humanidade que desconsidera desigualdades de poder e capital, ou ainda sob indicações de que a tarefa política crucial reside em distribuir a agência dos modos mais diferenciados e amplos possíveis, o que se observa é um processo de reestruturação basilar das dinâmicas de ordenação social no Antropoceno. Trata-se de um momento histórico em que antigas categorias conceituais e modos convencionais de pensamento e cognição deixam de corresponder às necessidades prementes de um tempo marcado pela urgência e em aceleração.

Dessa forma, concluímos que a noção de Antropoceno se apresenta como ideia-força6 de enorme potencial para os esforços de compreensão, análise e atuação prática na realidade histórica do século XXI. Ao mesmo tempo que busca constituir conceito científico rigoroso, a ideia de Antropoceno mobiliza um conjunto amplo de transformações, mudanças e metamorfoses culturais, políticas, ecológicas, econômicas e tecnológicas responsáveis por configurar a emergência de novas condições e possibilidades sócio-históricas. Ao propor, em sua última obra, a noção de "metamorfose" como chave explicativa dos processos contemporâneos de mudança social, Beck (2018) nos indica que "a metamorfose implica uma transformação muito mais radical, em que as velhas certezas da sociedade moderna estão desaparecendo e algo inteiramente novo emerge" (BECK, 2018, p. 11). Diante de tal condição política e existencial, lembra o autor, é preciso redefinir nosso modo de estar no mundo, de pensar sobre o mundo, de imaginar e fazer política, reconhecendo as consequências e implicações profundas de se viver na era dos efeitos colaterais.

Em termos teórico-metodológicos, isso significa localizar as discussões e debates acerca do Antropoceno em um campo de possibilidades conceituais e relações de definição eminentemente amplo e plural. As diferentes maneiras de conceber as relações entre Natureza, Sociedade e Cultura mobilizadas pela ideia-força de Antropoceno implicam, assim, diferentes movimentos de redefinição das interações entre agência, estrutura e mudança social no contexto sócio-histórico das sociedades industriais modernas. Categorias analíticas caras às tradições intelectuais consolidadas em teoria social, tais como classe, nação e Estado, perdem poder explicativo diante de novos referenciais teóricos e práticos,

como o “mundo”, o “planeta” e a “humanidade”. Segundo observamos, a noção de Antropoceno representa aporte decisivo para a tarefa de navegar nos mares tempestuosos das profundas mudanças e transformações de um mundo em metamorfose.

AGRADECIMENTOS

Os autores são gratos à Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (Capes), Fundação de Amparo à Pesquisa do Estado de São Paulo (Fapesp) – processo n.19/14867-2, pelo apoio financeiro aos nossos projetos de pesquisa, e ao Espaço da Escrita – Pró-Reitoria de Pesquisa – Unicamp, pelos serviços de tradução prestados. Gostaríamos também de agradecer aos revisores os cuidadosos comentários e sugestões realizadas acerca de nosso manuscrito.

NOTAS

1. Antes do presente – Before present (BP) – indica a sistematização da contagem de tempo para eventos geológicos, em que o “presente” é definido como a data calendário de 1950. Lewis e Maslim (2015).

2. Cf. Bauer e Ellis (2018), Ellis (2011), Ruddiman (2003, 2013), Steffen, Crutzen e McNeill (2007), Steffen et al. (2011, 2015), Trischler (2016), Waters et al. (2016) e Zalasiewicz et al. (2017, 2018).

3. Cf. LeCain (2015), Malm e Hornborg (2014) e Moore (2015, 2016).

4. Cf. Bauer e Ellis (2018), Chakrabarty (2018), Haraway (2015, 2016), Latour (2017), LeCain (2015), Malm e Hornborg (2014) e Moore (2015, 2016).

5. O debate a respeito da atuação humana na configuração da paisagem e da biodiversidade de diferentes localidades conta com múltiplas perspectivas e eixos analíticos distintos. Nesse particular, devemos mencionar a rica contribuição proporcionada pela Arqueologia na discussão de tais processos históricos de interconexão fundamental entre dimensões sociais, culturais, biológicas e ecológicas. Há todo um campo de investigação e análise, denominado Ecologia Histórica, que recentemente tem se voltado à consideração de semelhantes problemáticas, sob uma perspectiva bastante inovadora e instigante. Cf., a título de ilustração, Balée (2006, 2008), Neves e Petersen (2006), Rival (2006) e Roosevelt (2013).

6. Por “ideia-força”, entendemos a categoria de conceitos analíticos que se desdobram em múltiplas perspectivas, abordagens e orientações teóricas, muitas vezes conflitantes entre si. Ao mesmo tempo, são conceitos que implicam em pontos de referência normativa, ética e política que se pretendem comuns e consensuais. A ideia de desenvolvimento sustentável pode ser considerada exemplo paradigmático de semelhante categoria conceitual (FERREIRA, 2006; VEIGA, 2008). Além disso, conceitos político-normativos como “liberdade”, “democracia” e “justiça” também podem ser entendidos segundo tal perspectiva (MEADOWCROFT, 2007).

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Structural model of university social responsibility

Modelo estructural de responsabilidad social universitaria

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doi:10.18472/SustDeb.v12n2.2021.37345

Received: 07/04/2021
Accepted: 01/08/2021

ARTICLE – VARIA

ABSTRACT

The study aims to analyze the University Social Responsibility (USR) policy implemented at the Michoacan State University (*Universidad Michoacana de San Nicolás de Hidalgo - UMSNH*) from the perspective of the university community. For that purpose, a Structural Equations Model in its variant of Partial Least Squares (PLS) was used from a theoretical/empirical construct on the USR. Five variables integrated into 17 indicators were used, obtained by a representative sample. The results are presented in two sections; a) USR performance at the *UMSNH* and; b) the role of each variable in the PLS model. It is concluded that the performance was regular and the Internal Management (IM) had a key impact on the model operation. In the management practice, this might help identify areas to improve the performance of this policy by sector and variables.

Keywords: University Social Responsibility. Sustainable Development. USR Institutional Performance. Partial Least Square.

RESUMEN

El objetivo del estudio fue analizar la política de Responsabilidad Social Universitaria (RSU) implementada en la Universidad Michoacana de San Nicolás de Hidalgo (UMSNH) desde la perspectiva de la comunidad universitaria. Para ello se empleó un Modelo Estructural de Mínimos Cuadrados Parciales (PLS) a partir de un constructo teórico/empírico sobre la RSU. Se emplearon cinco variables integradas en 17 indicadores, obteniendo la información mediante una encuesta a una muestra representativa. Los resultados se presentan en dos apartados: a) descripción sobre el desempeño de la RSU en la UMSNH y; b) rol de cada variable en el modelo PLS. Se concluye que el desempeño de la RSU fue regular y que la Gestión Organizacional (GO) tuvo un impacto clave en el funcionamiento del modelo. En la practica administrativa, esto podría ayudar a identificar áreas de oportunidad para mejorar el desempeño de esta política por sectores y variables.

Palabras clave: Responsabilidad Social Universitaria. Desarrollo Sustentable. Desempeño Institucional. Partial Least Square. Universidad Michoacana de San Nicolás de Hidalgo.

1 INTRODUCTION

The University Social Responsibility (USR) has been established as a comprehensive management policy. It highlights internal processes and promotes good practices to respond to organizational and socio-environmental impacts of the university. It is distinct from the traditional solidarity extension as a unilateral declaratory commitment, compelling each university to put its epistemic assumptions and hidden curriculum under consideration (VALLAEYS, 2007).

Located in Michoacan, Mexico, the *Universidad Michoacana de San Nicolás de Hidalgo* (*UMSNH*) began, in 2007, an environmental management model called Institutional Environmental Plan. In 2014 it formally established the concept of the USR, as a result of a postgraduate course lead by Dr François Vallaeys, in which continuous improvement lines, USR program activities and permanent training plans were established (LÓPEZ, M. T. V.; LÓPEZ, M. V., 2016, p. 3).

It is assumed the possibility USR policy impacts differently on each university actor but might show a general trend. Structural analysis can reveal the impact of variables and by university sectors in the performance of the USR policy. The aims of this study are: 1) quantify the performance of the USR, by sectors and as a whole, and 2) analyze the impact by variables. For this purpose, a Partial Least Squares (PLS) analysis was performed. The proposed variables were: Environmental Resource Management (ERM), Internal Management (IM), Social Responsibility Training (SRT), University Social Projection (USP) and; Knowledge Production and Management (KPM).

To accomplish the objectives, the present article is integrated into five sections. The first one examines the concept of the USR and sustainable development, followed by the USR background in the *UMSNH*. In the third section, the information-gathering techniques and instruments used are explained. Then, in the fourth section, the results were presented, and finally, the conclusions are highlighted.

2 SUSTAINABLE DEVELOPMENT AND THE USR

Sustainable development has been a point of reference for social aspirations and it is generally a fundamental part of development policy discourses. However, the environmental crisis continues to move forward and the strategies to restrain it have been insufficient. The USR proposes to go beyond the attention to the negative environmental impacts and collates with sustainable development. This section presents theoretical literature and case studies. It begins with a description of the socio-environmental crisis and reflects critically on the scope of the USR.

The current socio-environmental crisis has been the result of social, political and economic interactions of capitalism that have accelerated the trends of ecological degradation and social conflicts over natural resources, as well as causing an increase in poverty, ignorance and injustice, which represents a threat to world prosperousness, security and stability, increasing social conflicts in different areas. Public and private actions have been towards disengagement between the practice of ecological policy and socio-environmental accounting (EARTH CHARTER, 2000; FOLADORI; TALKS, 2001; MARTÍNEZ, 2008; MURGA-MENOYO, 2009; QUINCHÉ-MARTÍN; CABRERA-NARVÁEZ, 2020; TOMMASINO, LEFF, 2002).

Some of the approaches to the socio-environmental crisis, propose paradigm shifts towards environmental rationality (LEFF, 2002). Meanwhile, the USR responds to this crisis from universities as active actors with a key role in development due to the presence and impacts on the stakeholders (VALLAEYS; CARRIZO, 2006). Thus, it is proposed that the university should continuously improve the organizational structure, being part of a transparency system, under the scheme that education and public awareness are key to leading society to achieve sustainability (CHIRINOS; PÉREZ, 2016; FUENTES; VALLAEYS; CASTRILLÓN, 2018; MCKEOWN et al., 2002). However, the university organizational structures are mostly too rigid to undertake profound changes both in the short and medium terms.

The criteria used for the USR management has considered three levels: 1) internal, (students, professors, researchers, authorities and administrative staff); 2) external, (employers, graduate students, suppliers and direct strategic partners) and, 3) global environment, (trends and general interactions) (GASCA; OLVERA, 2011). Thus, the USR and sustainable development promote a university projection that considers dissemination criteria, practice, principles and values in management, teaching, research and extension, reexamining its actions in a new social, ethical, democratic, equitable, transparent, helpful and self-organizing project (ESCUTIA; MEJÍA, 2011; NÚÑEZ, 2013; VALLAEYS, 2013; VALLAEYS; CARRIZO, 2005), assumed as Social Responsibility Training.

Hense, the responsible management of environmental resources is key, under the challenge of mainstreaming the curricular content of the courses and the pedagogical guidelines for the university community. Which was demonstrated in academic training, fostering changes in socially responsible behaviour in students being consciously manifested in emotional, cognitive and empathic processes, concerned and capable of taking the perspective of others (ARANGO et al., 2014). In this sense, the University promotes the education of public awareness, and an indisputable moral and existential commitment in the promotion of sustainable development, beginning with the encouragement of justice, freedom and social equality based on its substantive functions.

Some cases stand out such as, the Universidad de Francisco de Vitoria (Spain) which has incorporated a social responsibility subject into the study program since 1993, showing a significant impact from the students, concerning the social commitment towards others, the environment and the professional practice (RAMOS et al., 2016). In Perú, a study among 18 universities shows that the influence of the USR on the organizational culture, at the moment, has had little impact, which may be due to the lack of the USR program's transversality. However, the variables: teaching-learning, research, technological development and innovation, do show incidence (LIMO; PEÑA, 2019). The challenges range from changes in focus towards the learner, (which questions the common practice), to the teaching practice itself and the motivation in training and the transference of values, highly correlated with the motivation and demoralization of professors (IZARRA, 2019; YURÉN; GARCÍA; BRISEÑO, 2019).

At the Universidad de León in Spain, the impacts of university students and their satisfaction regarding the USR were analyzed. Using a Partial Least Squares (PLS) model, with 46 items in four variables, it was found that students can differentiate the facets of the USR, but only the Internal Management (IM) affected the general perception of the USR. Meanwhile, the global perception of the USR was also a determining factor in students' satisfaction (VÁZQUEZ; AZA; LANERO, 2016).

Thus, higher education institutions play a fundamental role in influencing society through their own human resource training strategies. In Brazil, entrepreneurial culture and student satisfaction are related in a positive and highly significant manner to the USR, using 11 indicators for student satisfaction, seven for entrepreneurial culture and 26 for the USR, through PLS analysis (SÁNCHEZ-HERNÁNDEZ; MAINARDES, 2016).

From the overhaul made, some reflections can be extracted:

I. Universities play a prominent role in influencing the solution of the current socio-environmental crisis. However, the scope is still limited related to circles of influence, generally young adults, less in childhood, adolescence and trained professionals. Therefore, the USR should also recommend a greater spectrum of action and social scope.

II. The universities' organizational structures are generally rigid and with little possibility of responding to social changes in the short term. Although the USR has been gradually positioned, it is not the rule but the exception.

III. Under this context, the USR proposes changes in behaviour that range from the continuous questioning of habits in the socio-environmental impact to the capitalist logic of seeking alternatives and new paradigms. However, the universities' own internal socio-political dynamics, make it difficult to internalize the USR and/or different policies that recommend changes, which operate when the external environment and favourable internal circumstances continually excerpt pressure.

IV. It is important to think over the need to overcome committed volunteering towards more mandatory schemes, as is already recommended for Social Responsibility Management. The implementation of legal frameworks and public policies capable of orienting markets towards responsible production and consumption, which do not systematically cause negative impacts, go through the law first before goodwill. Rather than a mandatory scheme, a global economic reorientation should be made, with commitments to sustainability (VALLAEYS, 2020).

Finally, some incidental elements in the USR can be highlighted: 1) Environmental Resource Management (ERM); 2) Internal Management (IM); 3) Social Responsibility Training (SRT); University Social Projection (USP) and Knowledge Production and Management (KPM) for the USR. After five years of having implemented the USR in the *UMSNH*, the proposed hypothesis is that through a PLS structural model, the interaction between variables and actors could be identified, so that the indicators that most influenced the implementation of the *Nicolaita* USR could be known.

3 BACKGROUNDS - THE USR IN THE UMSNH

In the actions taken by the *UMSNH's* environmental management agenda, these stand out: 1) electrical waste management since 2012, (*Recoelectrón*); 2) ecological footprint analysis in the *UMSNH,* as an environmental education mechanism; 3) USR actor training Diploma course is offered, being the professors a key part in all substantive activities (PÉREZ; VALLAEYS, 2016). Additionally, the *UMSNH* has participated with: 1) the Regional Observatory of Social Responsibility in Latin America and the Caribbean (*ORSALC-UNESCO*); 2) the founding of the Mexican Observatory of University Social Responsibility *(OMERSU);* 3) Venue of the First Meeting of Social Responsibility in Mexican Universities (GARCÍA, E. S.; GARCÍA, R. F., 2014); 4) in 2016 it formalized the First Committee for Regional Development and Social Responsibility of the Central West Region of *ANUIES* and; 5) in 2017, the UMSNH hosted the Second USR International Forum (GARCÍA; AGUILAR, 2017).

4 MATERIALS AND METHODS

The population under study was the UMSNH, 2017 from the registration in the official database, a sample of the following 26 university faculties was obtained; School of Medicine, Dentistry, Pharmacology, Psychology, History, Literature, Law, Fine Arts, Economics, Accounting, Veterinary Medicine, Civil Engineering, Philosophy, Mechanical Engineering, Chemical Engineering, Electrical Engineering, Wood Technology Engineering, Architecture, Biology, Physical Mathematics, Nursing; Institutes of Mechanical Engineering, Natural Resources Research and Agricultural and Forestry Research.

The studied sectors were: authorities, academics, administrative staff and students enrolled in 2017. The sample was obtained from the database provided by the UMSNH Human Resources Department and the Student Services Department. The sample size was obtained from the formula, n = (Z ^ 2 pqN) / ((NE) ^ 2 + Z ^ 2 pq) (Table 1), (values for the sample, Z = 1.96; p = 0.5; q = 0.5; E = 0.05). As the effective sample, it consists of the number of interviews obtained, which maintain an acceptable level of significance and representativeness.

Table 1 | Universe, population and study sample

Universes	*Population*	*Minimum sample size*	*Effective simple*	*Value of Z*
Authorities	130	26	16	12% from total*
Professors	2,445	332	226	1.60
Students	36,121	380	383	1.96
Administrative staff	799	259	205	1.65
Total population	39,495	991	705	

**For small populations, a sample slightly greater than 10% of the population was obtained.*
Source: Own elaboration based on the UMSNH Human Resource Department and the Student Services Department, 2017.

4.1 VARIABLES AND SURVEY DESIGN

From the study and the analysis of the USR variables and indicators used in other studies (ARANGO *et al*., 2014; AUSJAL, 2009; CANTÚ, 2013; GASCA; OLVERA, 2011; IESALC, 2008; IZARRA, 2019; LIMO; PEÑA; 2019; RAMOS *et al*., 2016; VALLAEYS; CARRIZO, 2006), the USR at the UMSNH, comprises five areas: environmental, organizational, educational, social and knowledge. The variables used were: Environmental Resource Management (ERM) (four indicators); Internal Management (IM) (four indicators); Knowledge Production and Management (KPM) (three indicators); Social Responsibility Training (SRT) (four indicators) and University Social Projection (USP) (two indicators) (Table 2).

For data collection, a personal interview questionnaire was used and the design established for the final version of the measurement instrument was integrated into three sections: 1) folio number, the universe and the research name; 2) respondents' profile, varying according to the universe and 3) variables, indicators, their respective items and the measuring scale by intervals (Likert-type scale).

To estimate the questionnaire's reliability, Cronbach's alpha coefficient (***α***) was used, showing consistency for the four measurement instruments in the pilot test. The results of ***α*** were: excellent in professors (0.943), administrative staff (0.915) and students (0.927); and acceptable in authorities (0.782) (BOJÓRQUEZ *et al*., 2013; GONZÁLEZ; PAZMIÑO, 2015). Once the instrument was verified, the data was obtained by applying face-to-face interviews by sectors: authorities, professors, administrative staff and students, with a response time between 10 and 15 minutes.

4.2 PARTIAL LEAST SQUARES USE (PLS) TECHNIQUE

The research was supported by the Structural Equation Modeling (SEM) that allows multiple regressions between latent variables (BARROSO; CEPEDA; ROLDÁN, 2005). To develop the methodological process of the tools' conditions and applicability for multivariate analysis (LÉVY; VARELA, 2003), it was decided to use the PLS modelling which is more appropriate for the prediction of the variables, high complexity and theory development (exploratory analysis) (CHIN, 2010). The variance of the dependent variables explained by the independent variables is maximized, instead of reproducing the empirical covariance matrix (HAENLEIN; KAPLAN, 2004). Furthermore, since the focus estimates the latent variables as linear combinations of the measurements.

These models identify how internal and external factors affect the analyzed variables, considering the way these variables could be interrelated. The PLS assumes that each construct plays the role of a theoretical concept represented by indicators, and the relationships between constructs must be established taking into account the prior knowledge (theory) of the phenomenon under analysis (LOEHLIN, 1987). The PLS is based on an iterative algorithm and the parameters are calculated by Least Squares regressions. The term Partial is due to the iterative procedure that involves separating the parameters instead of estimating them simultaneously (BATISTA-FOGUET; COENDERS, 2000; HAENLEIN; KAPLAN, 2004; ROLDÁN; SÁNCHEZ-FRANCO, 2012).

With the obtained results, a model is built that allows us to see the interrelationships between the USR variable, focusing on maximizing the variance. The results identify the factors that most impact each of the indices, thereby supporting the decision taken by knowing the impact by variable.

4.3 LATENT AND OBSERVED VARIABLES

One of the most relevant concepts for SEM is latent variables. These are not directly observable or measured by a generally accepted instrument (SCHUMACKER; LOMAX, 2004). Latent variables are constituted of manifest variables, observed variables or indicators. In the PLS Path Modeling, the latent variables will be obtained as a linear combination of the observed group variables (indicators) (LOEHLIN, 1987). It is assumed that any measurement will be imperfect, as shown (HAENLEIN; KAPLAN, 2004), each observation in the real world comes with a measurement error compound by two parts: (a) random error (caused by the order of the items in a survey or by the respondent bias); and (b) systematic error, due to the variance. Therefore, the observed value of an item is constituted by: 1) the variable's true value; 2) the random error and, 3) the systematic error.

The PLS provides a framework for analyzing multiple relationships between constructs. It is assumed that each construct plays the role of a theoretical concept represented by its indicators, and the relationships between constructs must be established taking into account the prior knowledge (theory) of the phenomenon under analysis. In summary, the PLS can be a powerful tool due to the minimum demands of measurement scales, sample size, and residual distributions (CHIN, 2010). To develop the methodological process, the following survey was developed based on the variables, see Table 2.

The results obtained from the indicators were incorporated by dimension in the PLS smart 3.0 software, grouping by dimensions and variables. Then, a form of relationship between variables is suggested, generating the latent variables based on the expected relationship between them. The following step is to run the interaction in the proposed relationship, the application makes the calculations until it reaches the variable convergence or stability. After several tests, the statistical consistency indicates the model reliability and the interpretation capacity in the integrated variables modelling by the groups of indicators.

Table 2 | Variables Operationalization

Variables	*Dimensions*	*Indicators*	*Clave*
Environmental Resource Management (ERM)	Ecosystem Protection	Institutional Environmental Plan (EPI) Knowledge	PE
		Green areas sufficiency	PE2
		Green areas protection and carefulness	PE3
	Waste Management	Recycling bin for solid waste separation	MRA1
		Solid waste sorting knowledge	MRA2
		Solid waste correct disposal	MRA3
	Energy Use	Efficient use of energy	UE1
		Energy generation	UE2
	Water Treatment and Care	Efficiency in the water use	TCA1
		Water care	TCA2
	Influence in Ecological Behaviors	Paper sheets reuse	ICE1
		Ecological footprint knowledge	ICE2
		Low impact mobility promotion	ICE3
		Disposable reduction	ICE4
		Influence of the EPI on ecological habits	ICE5
		Efficient use of water	ICE6
Internal Management (IM)	Nicolaita Identity	Attention to vulnerable population	IN1
		The practice of the principle of humanism	IN2
	Work Environment	Study environment	AL1
		Regarding diversity	AL2
	Remuneration and Training	Perception of equity	RC1
		Perception regarding salary/remuneration	RC2
		USR training	RC3
	Participation and Democracy	Democratic values perception	PD1
		Gender equality	PD2
Social Responsibility Training (SRT)	USR Training	Environmental content	CRS1
		Contingency strategies training	CRS2
	Multidisciplinary Training	Social project training	FM1
	Interinstitutional Training	Inclusion in university projects	FI1
		Project participation with other universities	FI2
	Critical Reflection Training	Social problems awareness	FR1
		Profession role in society	FR2
		Perception of accomplishment	FR3
University Social Projections (USP)	Extension	Link with environmental causes	EX1
		Participation in environmental causes	EX2
	Academic Linkage	Links with deprived sectors of society	VN1
		University job bank	VN2
Knowledge Production and Management (KPM)	Socially Useful and Relevant Research	The research applied to vulnerable social groups	IP1
		General research linkage	IP2
	Multidisciplinary Knowledge	Development projects with other sectors	CM1
		Student/professors participation in research	CM2
	Sustainability Knowledge	Self-knowledge promotion	CS1
		The research applied to improve USR	CS2

Source: Information obtained from the theoretical framework.

5 RESULTS

5.1 NICOLAITA USR PERFORMANCE

The USR performance in the *UMSNH*, on a scale with a maximum of 5.0, for authorities was 3.57, for professors 3.25 and very close to 3.0 for both administrative staff and students. The average indicates regular performance. The IM shows the best performance (3.6) and the lowest variance (0.022), while the lowest performance was for SRT and USP, both with a value of 3.0. (Table 3). Table 4 shows the global performance by sectors of the parametric statistics where the central tendency and distribution measures can be observed, finding the highest performance for AUT and the lowest for AS, very close to ST, as well as the highest variance among the professors' sector (PF).

Table 3 | USR-UMSNH Average Performance

	Administrative Staff (AS)	*Professors (PF)*	*Authorities (AUT)*	*Students (ST)*	*Average***	*Variance*
ERM	2.99	3.02	3.35	3.08	3.111	0.027
IM	3.54	3.66	3.84	3.52	3.641	0.022
SRT	2.78	3.07	3.14	3.05	3.012	0.026
USP	2.90	3.20	3.63	2.59	3.077	0.197
KPM	3.14	3.30	3.89	2.99	3.328	0.154
*Average**	3.07	3.25	3.57	3.04		
Variance	0.088	0.064	0.102	0.110		

** Average by sectors (groups) from the averages per variable.*
***Average per variable based on averages by sector.*
Source: Own elaboration with field data.

Table 4 | Descriptive statistics for the global average performance of USR

	AS	*AUT*	*PF*	*ST*
*Media**	3.089	3.545	3.225	3.128
Typical error	0.042	0.094	0.044	0.032
Median	3.073	3.586	3.214	3.150
Mode	2.805	3.857	3.238	3.125
Standard deviation	0.605	0.374	0.656	0.624
Sample variance	0.366	0.140	0.430	0.390
Kurtosis	-0.367	1.802	-0.665	-0.153
Asymmetry coefficient	0.179	-1.254	0.090	-0.156
Range	2.951	1.429	2.857	3.625
Minimum	1.83	2.57	1.86	1.30
Maximum	4.78	4.00	4.71	4.93
Sum	633.27	56.71	728.93	1198.18
Observation (n)	205	16	226	383

** Average from the concentrated information*
Source: Own elaboration with field data.

5.2 PLS-SEM MODEL FOR THE NICOLAITA USR PERFORMANCE

A three-step process was followed for the PLS use: 1) the weights of the relationships, which link the indicators to their respective latent variables and are estimated; 2) the case values are calculated for each latent variable based on the indicators weighted average; 3) these case values are used in a group of regression equations to determine the parameters of the path or structural coefficients (HAENLEIN; KAPLAN, 2004). The algorithm returns to the relations of the measurement model where new weights (outer weights) are calculated and the process continues iteratively until the convergence of the weights is reached. See Figure 1.

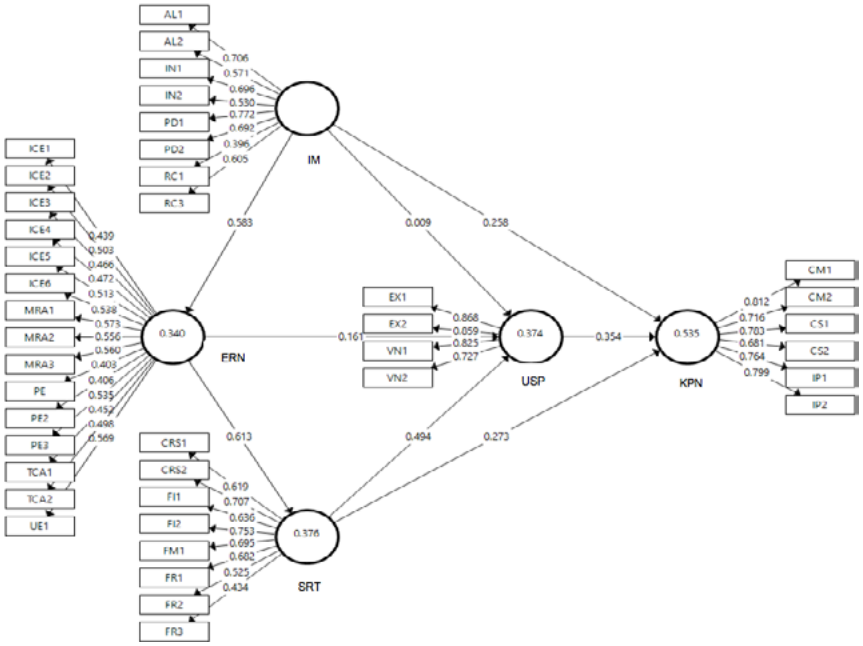

Figure 1 | UMSNH University Social Responsibility Structural Model

Source: Personal elaboration in Smart PLS, V. 3.0, based on field information.

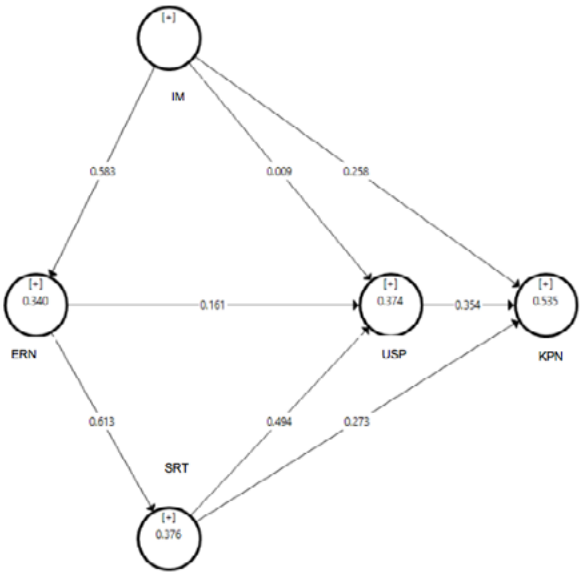

Figure 2 | University Social Responsibility Variables Model

Source: Personal elaboration in Smart PLS, V. 3.0, based on field information.

In Figure 1, the structural model is seen in graphic form and represents the relationships between constructs that are hypothesized in the proposed model. To analyze the structural model with PLS a recursive model is needed, meanings that loops are not allowed in structural relationships. Because the primary objective of the PLS is prediction, the accuracy of the model is evaluated by two main indices: the coefficients of the structural paths and the combined predictivity (R^2) of the endogenous constructs (CHIN, 2010). (DUARTE; RAPOSO, 2010), used the criterion that the explained variance (R^2) for endogenous variables must be greater than 0.1.

In Figure 2, the evaluation of the coefficients path described that these coefficients have standardized values, approximately between -1 and +1. Coefficients closer to +1 indicate a strong positive relationship, in contrast to -1, while coefficients close to 0 indicate weakness with no significance. Table 5 describes the relationships between the constructs based on the coefficients path representing the hypothesized relationships between the constructs. It can be fully appreciated that the most significant relationship is the ERM variable (0.583) with the SRT variable (0.613) and the least significant relationship is that of the IM with the USP (0.009).

Table 5 | Coefficients Path

	SRT	*IM*	*KPM*	*ERM*	*USP*
SRT			0.273		0.494
IM			0.258	0.583	0.009
KPM					
ERM	0.613				0.161
USP			0.354		

Source: Personal elaboration in Smart PLS, V. 3.0, based on field information.

The coefficient of determination (R^2) is the most used to evaluate a structural model and is a measure of the model's predictive capability. This is calculated as the square of the correlation between an endogenous construct and the predicted values. It represents the amount of variance in the endogenous construct explained by all the endogenous constructs linked to it. The values of R^2 from 0 to 1, with levels close to the unit R^2, indicate a higher level of predictive precision.

In Table 6, it is described that the KPM variable for the USR is the one that presents the highest indicators, R^2 by 0.535 and R^2adj 0.533, they can also be seen graphically in Figures 1 and 2. In Table 6, it is possible to notice that both the Cronbach's Alpha coefficient and the Composite Reliability measure are higher than 0.70, so that each of the constructs shows validity and internal consistency. Concerning the Average Extracted Variance, two variables show a value greater than 0.53, USR with 0.675 and ERM with 0.252. The results show that the Structural Model have robust constructs since the validity levels are accepted and give high reliability to the values obtained by the latent variables based on the observable variables.

Table 6 | Reliability, Construct Validity and Determination (R^2)

Variables	*Cronbach's Alpha*	*rho_A*	*Compound reliability*	*Media extracted variance (AVE)*	*R^2*	*$R^{2\ Adjusted}$*
SRT	0.788	0.805	0.843	0.408	0.376	0.375
IM	0.778	0.802	0.837	0.398	--	--
KPM	0.853	0.856	0.891	0.578	0.535	0.533
ERM	0.786	0.789	0.833	0.252	0.340	0.339
USP	0.838	0.843	0.892	0.675	0.374	0.372

Source: Personal elaboration in Smart PLS, V. 3.0, based on field information.

When performing the process of each of the indicators using the PLS-SEM technique, the factors that affect each index are shown, considering those with a total effect greater than 0.40, as seen in Table 8 and Figure 2. Based on the previous information, the correlation of latent variables was obtained (Table 7) and the indices were grouped, resulting in the variables as observed in Table 8. In which the KPM variable for the USR as the most significant is observed since it presents a positive association with each of the independent variables ERM, IM and SRT.

Table 7 | Latent Variables Correlation

Variables	*I*	*II*	*III*	*IV*
I. SRT				
II. IM	0.582			
III. KPM	0.635	0.555		
IV. ERM	0.613	0.583	0.505	
V. USP	0.598	0.390	0.618	0.469

Source: Personal elaboration based on the information obtained from the fieldwork using the PLS.

For the Heterotrait-Monotrait (HTMT) measurement, the value for the relationship between KPM and SRT was 0.764, for ERM and SRT 0.761 and between KPM and USP 0.734 (see Table 9). With these values, it is considered that the indicators that make up each of the proposed variables meet the discriminant validity criteria.

Following the procedure of Hair et al. (2016), the first step is the evaluation of any sign of collinearity, for which the VIF values were used, represented in Table 10. The SRT, IM and USP constructs are predictors of the KPM construct, and all the values are below the limit value of 5, so there is no collinearity between the constructs and thus, we can proceed to the evaluation of the structural model.

Table 8 | Affected Factors by Variable and Considered Index (total effect greater than 0.40)

KEY	*SRT*	*IM*	*KPM*	*ERM*	*USP*	*KEY*	*SRT*	*IM*	*KPM*	*ERM*	*USP*
AL1		0.706				ICE5				0.513	
AL2		0.571				ICE6				0.538	
CM1			0.812			IN1		0.696			
CM2			0.716			IN2		0.53			
CRS1	0.619					IP1			0.764		
CRS2	0.707					IP2			0.799		
CS1			0.783			MRA1				0.573	
CS2			0.681			MRA2				0.556	
EX1					0.868	MRA3				0.56	
EX2					0.859	PD1		0.772			
FI1	0.636					PD2		0.692			
FI2	0.753					PE				0.403	
FM1	0.695					PE2				0.406	
FR1	0.682					PE3				0.535	
FR2	0.525					RC3		0.605			
FR3	0.434					TCA1				0.452	
ICE1				0.439		TCA2				0.498	
ICE2				0.503		UE1				0.569	
ICE3				0.466		VN1					0.825
ICE4				0.472		VN2					0.727

Source: Personal elaboration based on the information obtained from the fieldwork using the PLS.

Table 9 | *Heterotrait-Monotrait Ratio (HTMT) Test Results*

Variables	*SRT*	*IM*	*KPM*
SRT			
IM	0.725		
KPM	0.764	0.664	
ERM	0.761	0.710	0.609
USP	0.723	0.464	0.734

Source: Personal elaboration based on the information obtained from the fieldwork using the PLS.

Table 10 | *VIF Values of Structural Model*

Variables	*SRT*	*IM*	*KPM*	*ERM*	*USP*
SRT			2.002		1.825
IM			1.517	1.000	1.725
KPM					
ERM	1.000				1.829
USP			1.563		

Source: Personal elaboration based on the information obtained from the fieldwork using the PLS.

As for the f^2 effects, values greater than 0.02 indicate there is an effect between the latent variables. In this case, it is considered the variables SRT with USP is 0.214, IM with ERM is 0.514, ERM with SRT is 0.602, mainly, since they all have values greater than 0.02, (see Table 11).

Table 11 | Efectf2

Variables	*SRT*	*IM*	*KPM*	*ERM*	*USP*
SRT			0.080		0.214
IM			0.094	0.514	
KPM					
ERM	0.602				0.023
USP			0.173		

Source: Personal elaboration based on the information obtained from the fieldwork using the PLS.

5.3 DISCUSSION OF RESULTS

The investigation was presented with a model showing validity; therefore, the results are reliable to perceive what happens between the interaction of variables and indicators of the USR implemented in the *UMSNH*. The statistical description presents a quantifiable performance and the structural model is consistent with the expected results from the perception of the university actors.

The USR has been a management instrument to promote a change in socio-environmental culture and which seeks to impact society. The present work has reviewed the implementation of the USR in the *UMSNH* evaluated from the actors' perception through five years. The overall average performance was fair, with values close to 3 out of 5 possible points. This implies that in the *Nicolaitas* global perception, the USR has provided regular, rather than good or excellent results.

One of the most relevant results is shown in Table 8, indicating the impact that each index had per variable. For example, for SRT two indicators showed greater relevance: CRS2 and FR1, and significant relevance: FI1, FI2, FM1, FR2, FR3, CRS1. This is important when evaluating the aspects that should be strengthened to improve the USR and the type of expected effect.

Another element that provides valuable information for the USR is that three variables have the greatest directional impact on the entire model, these being: SRT, IM and KPM, which can help to improve the results of the USR's implementation to impact ERM and USP more efficiently, suggesting that, to have better results in the performance of the USR, the performance in these three variables is fundamental; more so, the performance in the most influential indicators.

The objectives set for quantifying the variable performance on the USR and the impact of each variable served for measuring the relationships between the indicators and the variables. At the level of the variable interaction, the IM has a directional impact on the ERM both variables are operative, meaning highly visible in practice, which may explain the direction and intensity of the impact.

One of the most heterogeneous indicators is the USR training, in which authority appears high and with a wide difference with the administrative staff and professors. It can also be noticed that the sectors with the highest variance were AUT and ST, which suggests a very different perception of both sectors that may also denote a bias in the responses, given their political pose. Which represents one of the job's weaknesses.

It also highlights that the SRT has a relatively considerable impact on the USP since it deals with bounding and university extension with the environment. At the same time, the SRT impacts the KPM, although to a lesser extent. As expected, the KPM is directly impacted by three paths with the variables USP, SRT and IM; this would be explained because the generated knowledge is directly related to academic training, university policy and the university projection. In summary, the trials show expected relationships, however; low coefficients would indicate a regular performance of the USR.

The low value for USP would reflect the lack of bonding with the outside, a not isolated situation in the Ibero-American universities that have implemented the USR and maintain the practices in diverse social environments, as one of their main challenges, relating their policies to the problems in their communities, (AYALA-RODRÍGUEZ *et al*., 2010). This implies considering Higher Education a common good, incorporating the stakeholders into the governance, and including in its action focus not moving away from its immediate reality, in the search for an international ranking (MARTÍ-NOGUERA; LICANDRO; GAETE-QUEZADA, 2018).

An unresolved aspect in the exploration of the results is the expectation and monitoring of the patterns that the USR instils on the actors involved outside of the university campuses. As shown by some studies around, graduate students give high importance to USR in their expectations and it may influence behaviours and inclusion of categories and topics related to ethics, environment and sustainable development (ESPITIA-CUBILLOS; MENESES-PORTELLA; HUERTAS-FORERO, 2020). Thus, the results show the interaction between the variables from the perspective of the actors, but it is still pending to complement the perceptions from the thematic categories; especially for the academic community.

It should also be noted that the response of universities to the current socio-environmental crisis finds conceptual and practical support in the USR which constitutes an important challenge because it touches sensitive fibres in different dimensions of the process. It ranges from the production of knowledge and the "hidden" curriculum to teaching methods and formal content (ARANGO *et al*., 2014; CHIRINOS; PÉREZ, 2016; GASCA; OLVERA, 2011; NÚÑEZ, 2013; RODRÍGUEZ *et al*., 2020; VALLAEYS, 2013; YURÉN; GARCÍA; BRISEÑO, 2019). As could be seen in the case study, a change in behaviour is slow and implies strategies that seek synergies to improve performance, in the beginning, the main variables (such as IM), but then it is necessary to insist on the approach of new paradigms beginning with knowledge and followed by example, in the adoption of standards, which are not always popular at first.

Another aspect the USR explores is its function as a binding axis with social environment involving a variety of elements from consulting and technology transfer (MARTÍNEZ DE CARRASQUERO *et al.*, 2008); and the USR as social innovation (AGUIRRE; **GÓNZALEZ**, 2020); to the university role as a stakeholder, transmitting the concerns to all the areas of influence, not only employees, (professors

and administrative staff) and students (clients), but also the suppliers of material goods, services and financing (CONTRERAS; ANDRADE, 2012; GÓMEZ; NAVEIRA; BERNABEL, 2018). This is an aspect gaining importance, but it still faces barriers in the comprehensive implementation. However, in the sectors with direct involvement; (professors, researchers, authorities and administrative staff -employees- and clients -students-) there is a promising and favourable perspective.

6 CONCLUSIONS

The Policy regarding the installation of the USR management model has been around for five years at the time of performing this study and ten years since the Institutional Environmental Plan set the antecedent on environmental management in the *UMSNH*. The USR goes beyond the approaches on environmental management, covering areas such as principles of identity, social projection, organizational structure, democracy, freedom and gender equality. But the main focus is the role that the university plays in society. As can be denoted, progress has been made, but it is still necessary to continue improving this aspect.

The performance regarding the implementation of the USR in the *UMSNH* was regular, implying that there are still areas of opportunity to attend and improve. These areas can be found in the structural analysis. As expected, IM turns out to be a key variable in the model behaviour since it directly impacts ERM and KPM as well as SRT indirectly. Likewise, the most important management indicator was the labour environment. All that is present in knowledge-based societies and ecosystems. In this sense, the actions that impact this variable (particularly the AL1 indicator) will have an important effect on the behaviour of the model. As an area of opportunity, AL2 remains pending to improve its attentiveness.

One of the contributions of this work was to analyze the USR performance in the UMSNH, from a relatively new SEM-PLS Model. The results have shown the relationship between the variables and their expected behaviour. This model was represented by the constructs of five variables and 17 indicators.

The Cronbach's Alpha and Composite Reliability tests result established that each of the constructs showed validity and internal consistency. The most significant relationship was presented between the variables: ERM with SRT (0.613) and the least significant relationship is found between the IM variable with USP (0.009). From the Determination Coefficient calculation, it was possible to establish KPM for the USR being the one with the highest indicators, the R2 by 0.535 and the R2adj 0.533.

The variables ERM, SRT and KPM, showed the highest impacts and the greatest interaction in the USR. While the USP and the IM show areas of opportunity. Specifically, it could be denoted for each indicator in Figure 1, which summarizes the PLS-SEM result.

Among the limitations of the study and a pending research line, are the lack of representation of those who do not directly belong to the university (graduate students, independent professionals, companies, government and civil society). In this sense, the existence of a response bias regarding the actors participating in the research is likely.

The role of universities towards sustainable development is still a road under construction, however, efforts such as the USR policies show firm elements of progress in institutional commitment. Nonetheless, these measures have yet to be generalized and internalized in the communities so that their impact may become more noticeable. Once the USR in the UMSNH was analyzed we could see the most important variables to promote a higher positive impact in the USR. At the same time, we can notice the differences in perceptions among the university sectors, which should be considered in the monitoring strategy of the USR.

We, the authors, declare to have no conflict of interest when presenting the results of this research.

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Modelo estructural de responsabilidad social universitaria

Structural model of university social responsibility

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doi:10.18472/SustDeb.v12n2.2021.37345

Received: 07/04/2021
Accepted: 01/08/2021

ARTICLE – VARIA

RESUMEN

El objetivo del estudio fue analizar la política de Responsabilidad Social Universitaria (RSU) implementada en la Universidad Michoacana de San Nicolás de Hidalgo (UMSNH) desde la perspectiva de la comunidad universitaria. Para ello se empleó un Modelo Estructural de Mínimos Cuadrados Parciales (PLS) a partir de un constructo teórico/empírico sobre la RSU. Se emplearon cinco variables integradas en 17 indicadores, obteniendo la información mediante una encuesta a una muestra representativa. Los resultados se presentan en dos apartados: a) descripción sobre el desempeño de la RSU en la UMSNH y; b) rol de cada variable en el modelo PLS. Se concluye que el desempeño de la RSU fue regular y que la Gestión Organizacional (GO) tuvo un impacto clave en el funcionamiento del modelo. En la practica administrativa, esto podría ayudar a identificar áreas de oportunidad para mejorar el desempeño de esta política por sectores y variables.

Palabras clave: Responsabilidad Social Universitaria. Desarrollo Sustentable. Desempeño Institucional. Partial Least Square. Universidad Michoacana de San Nicolás de Hidalgo.

ABSTRACT

Aim of the study was to analyze the policy implemented in University Social Responsibility (USR) at the Michoacan State University (Universidad Michoacana de San Nicolás de Hidalgo -UMSNH-), from the perspective of the university community. To reach aim a Structural Equations Model in its variant of Partial Least Squares (PLS) were used from a construct about USR. The data was obtained in a representative survey. The results are presented in two parts: a) description of USR performance at UMSNH and; b) role of each variable in the PLS model, showing that relations and impacts between variables. It was concluded that the USR had a regular performance and more important variable was Organizational Management (GO) with an important impact, being a key at the RSU model. In management practice, it is necessary to identify opportunities to improve this policy.

Keywords: Social University Responsibility. Sustainable Development. Institutional Performance of SRU. Partial Least Square.

1 INTRODUCCIÓN

La Responsabilidad Social Universitaria (RSU) se ha conformado como una política de gestión integral que, desde procesos internos de las universidades, promueve buenas prácticas para responder a los impactos socio-ambientales organizacionales y académicos de la universidad. Se distingue de la tradicional extensión solidaria, como de un mero compromiso unilateral declarativo, a la vez que obliga a cada universidad a poner en tela de juicio sus presupuestos epistémicos y su currículo oculto (VALLAEYS, 2007).

Situada en Michoacán, México, la Universidad Michoacana de San Nicolás de Hidalgo (UMSNH), inició en 2007 un modelo de gestión ambiental denominado Plan Ambiental Institucional (PAI) en 2014 estableció formalmente el concepto de RSU, producto de un diplomado dirigido por el Dr. François Vallaeys, se establecieron líneas de mejora continua, programa de actividades de RSU y planes de capacitación permanentes (LÓPEZ, M. T. V.; LÓPEZ, M. V., 2016, p. 3).

Asumiendo la posibilidad de que la política de RSU impacta de distinta manera en cada actor universitario, pero que puede mostrar una tendencia general. Así como que un análisis estructural puede revelar el impacto por variables y por sectores universitarios en dicho desempeño de la política RSU. Los objetivos de este estudio fueron dos: 1) cuantificar el desempeño de la RSU, por sectores y en conjunto y, 2) analizar el impacto por variables. Para ello, se realizó un análisis de Mínimos Cuadrados Parciales (PLS, por sus siglas en inglés). Las variables propuestas fueron: Manejo de Recursos Ambientales (MRA), Gestión Organizacional (GO), Formación para la Responsabilidad Social (FRS), Proyección Social de la Universidad (PSU) y; Gestión y Producción de Conocimiento (GPC).

Para alcanzar los objetivos, el artículo se integra de cinco apartados, en el primero se revisa el concepto de la RSU y el desarrollo sustentable, seguido los antecedentes sobre la RSU en la UMSNH. En la tercera parte se explican las técnicas de recolección de información e instrumentos empleados. En la cuarta sección se exponen y discuten los resultados y, por último se destacan conclusiones.

2 DESARROLLO SUSTENTABLE Y RSU

El desarrollo sustentable ha constituido un punto de referencia para las aspiraciones sociales y generalmente forma parte en los discursos sobre políticas de desarrollo. Nos obstante, la crisis ambiental sigue avanzando y las estrategias para contenerla han sido insuficientes. La RSU se propone ir más allá de la atención a los impactos ambientales negativos y compatibiliza con el desarrollo sustentable. Este apartado, expone literatura teórica y estudios de casos. Inicia con una descripción de la crisis socio-ambiental y reflexiona críticamente sobre los alcances de la RSU.

La crisis socio-ambiental actual, ha sido resultado de interacciones sociales, políticas y económicas del capitalismo que ha acelerado las tendencias de: degradación ecológica y conflictos sociales por los recursos naturales, así como ha ocasionado incrementos en: pobreza, ignorancia e injusticia, lo que significa una amenaza a la prosperidad, la seguridad y la estabilidad mundiales, aumentado los conflictos sociales en diferentes ámbitos. Las actuaciones pública y privada han sido de desvinculación entre la práctica de la política ecológica y la contabilidad socio-ambiental (CARTA DE LA TIERRA, 2000; FOLADORI; TALKS, 2001; MARTÍNEZ, 2008; MURGA-MENOYO, 2009; QUINCHÉ-MARTÍN; CABRERA-NARVÁEZ, 2020; TOMMASINO; LEFF, 2002).

Algunos de los planteamientos para abordar la crisis socio-ambiental, proponen cambios de paradigma hacia una racionalidad ambiental (LEFF, 2002). En tanto, la RSU, responde a dicha crisis desde las universidades como actores activos con un papel clave en el desarrollo debido a sus pretensiones e impactos en las partes interesadas y afectadas (VALLAEYS; CARRIZO, 2006). Así, se propone que la universidad debe mejorar continuamente en su estructura organizacional, formar parte de un sistema de transparencia, bajo el esquema que la educación y la conciencia pública son claves para llevar a la sociedad a alcanzar la sostenibilidad (CHIRINOS; PÉREZ, 2016; FUENTES; VALLAEYS; CASTRILLÓN, 2018; MCKEOWN *et al.*, 2002). No obstante, las estructuras organizativas de las Universidades la mayor de las veces es demasiado rígidas para emprender cambios profundos tanto a corto como a medianos plazos.

Los criterios empleados para la gestión de la RSU, han contemplado tres niveles: 1) interno, (los estudiantes, docentes, investigadores, directivos y personal administrativo); 2) externo, (empleadores, egresados, proveedores y socios estratégicos directos) y, 3) ambiente global, (tendencias e interacciones generales) (GASCA; OLVERA, 2011). Así, RSU y desarrollo sostenible promueven una proyección universitaria que considera criterios de difusión, práctica, principios y valores en la gestión, docencia, investigación y extensión, re-pensando su actuar en un nuevo proyecto social, ético democrático, equitativo, transparente, servicial y auto-organizativo (ESCUTIA; MEJÍA, 2011; NÚÑEZ, 2013; VALLAEYS, 2013; VALLAEYS; CARRIZO, 2005), asumido como la Formación para la Responsabilidad Social.

Para ello, es clave el manejo responsable de recursos ambientales, bajo el reto de transversalizar el contenido curricular de los cursos y las directrices pedagógicas para la comunidad universitaria. Lo que se demostró en la formación académica, fomentando cambios en comportamientos socialmente responsables en los estudiantes, y se manifiestan de manera consciente en procesos emocionales, cognitivos y empáticos, preocupados por los demás y capaces de tomar la perspectiva del otro (ARANGO *et al.*, 2014). En este sentido, la Universidad promueve la formación de la conciencia pública, y un compromiso moral y existencial indiscutible en el fomento del desarrollo sostenible, empezando con la promoción de: justicia, libertad e igualdad social a partir de sus funciones sustantivas.

Destacan algunos casos como, la Universidad Francisco de Vitoria (España) ha incorporado en su plan de estudios desde 1993 la materia de responsabilidad social, lo que muestra un impacto significativo de los estudiantes, en el compromiso social con los demás, con el entorno y con el ejercicio profesional (RAMOS *et al*., 2016). En Perú, un estudio para 18 universidades muestra que, la influencia de la RSU en la cultura organizacional al momento ha tenido poca incidencia, lo cual puede obedecer a la falta de transversalidad del programa de RSU. No obstante, las variables: enseñanza - aprendizaje, investigación, desarrollo tecnológico e innovación, si muestran incidencia (LIMO; PEÑA, 2019). Los desafíos van desde cambios de enfoque hacia el aprendiente, (lo que cuestiona la práctica común), hasta la propia práctica docente y su motivación en formación y transmisión de valores, altamente correlacionado con la motivación y desmoralización de los docentes (IZARRA, 2019; YURÉN; GARCÍA; BRISEÑO, 2019).

En la Universidad de León en España, se analizaron los impactos de los universitarios y su satisfacción respecto a la RSU. Mediante un modelo de Mínimos Cuadrados Parciales (PLS), con 46 ítems en cuatro variables, se encontró que los estudiantes diferencian las facetas de la RSU, pero solo la Gestión Interna (GI) afectó la percepción general de la RSU. En tanto que, la percepción global de RSU también fue factor determinante en la satisfacción de los estudiantes, (VÁZQUEZ; AZA; LANERO, 2016).

Así, las instituciones de educación superior tienen un papel fundamental para influir en la sociedad, mediante sus propias estrategias de formación de recursos humanos. En de Brasil, la cultura emprendedora y la satisfacción de los estudiantes se relacionaron de manera positiva y altamente significativa con la RSU, empleando 11 indicadores para satisfacción estudiantil, siete en cultura emprendedora y 26 de RSU, mediante un análisis PLS (SÁNCHEZ-HERNÁNDEZ; MAINARDES, 2016).

De la revisión hecha se pueden extraer algunas reflexiones:

I. Las universidades tienen un papel destacado para influir en la solución de la crisis socio-ambiental actual. Sin embargo, su alcance aún es limitado en: círculos de influencia, generalmente adultos jóvenes, poco en la infancia, adolecencia y profesionistas ya formados. Por lo que la RSU también debiera plantear un ámbito de acción de mayor espectro y alcance social.

II. Las estructuras organizacionales de las universidades por lo general son rígidas y con escasas posibilidades de responder en el corto plazo a los cambios sociales. Si bien la RSU se ha posicionado gradualmente, no es la regla sino la excepción.

III. Bajo este contexto la RSU plantea cambios de comportamiento que van desde el cuestionamiento continuo de hábitos en el impacto socio-ambiental y la lógica capitalista para buscar alternativas y nuevos paradigmas. Sin embargo, las propias dinámicas socio-políticas internas de las Universidades dificultan la interiorización de la RSU y/o distintas políticas que propongan cambios, mismos que operan cuando el entonrno externo y circunstancias internas favorables presionan de manera continua.

IV. Es importante reflexionar en la necesidad de superar el voluntariado comprometido hacia esquemas de mayor obligatoriedad, como se plantea ya para la Responsabilidad Social Empresarial. La implementación de marcos legales y políticas públicas capaces de orientar los mercados hacia una producción y consumo responsables, que no produzcan sistemáticamente impactos negativos, pasa primero por la ley antes que por la buena voluntad, más que una obligatoriedad, se debiera hacer una reorientación económica global, con deberes para con la sustentabilidad (VALLAEYS, 2020).

Por último, se pueden destacar algunos elementos incidentes en la RSU: 1) Manejo de Recursos Ambientales (MRA); 2) Gestión Interna u Organizacional (GO); 3) Formación para la Responsabilidad Social (FRS); Proyección Social de la Universidad (PSU) y Gestión y Producción de Conocimiento (GPC) para la RSU. A cinco años de la implementación de la RSU en la UMSNH, se plantea la hipótesis de que mediante un modelo estructural PLS, se podría identificar la interacción entre variables y actores, de manera que se pueden conocer los indicadores que influyeron más en la implementación de la RSU Nicolaita.

3 ANTECEDENTES - LA RSU EN LA UMSNH

En las acciones de la agenda sobre gestión ambiental de la UMSNH, han destacado: 1) manejo de los residuos eléctricos desde 2012, (Recoelectrón); 2) Análisis de la Huella Ecológica en la UMSNH, como mecanismo de educación ambiental; 3) Se imparte el Diplomado de formación de actores en RSU, siendo los profesores pieza clave en todas las actividades sustantivas (PÉREZ; VALLAEYS, 2016). Adicionalmente, la UMSNH ha participado con: 1) el Observatorio Regional de Responsabilidad Social en América Latina y el Caribe (ORSALC-UNESCO); 2) Fundación del Observatorio Mexicano de Responsabilidad Social Universitaria (OMERSU); 3) Sede del Primer Encuentro de Responsabilidad Social en las Universidades Mexicanas (GARCÍA, E. S.; GARCÍA, R. F., 2014); 4) en 2016 formalizó el Primer Comité de Desarrollo

Regional y Responsabilidad Social de la Región Centro Occidente de la ANUIES y; 5) en 2017 la UMSNH fue sede del Segundo Foro Internacional de RSU (GARCÍA; AGUILAR, 2017).

4 MATERIALES Y MÉTODOS

La población objeto de estudio fue la UMSNH, en el año 2017 a partir del registro en la base de datos oficiales, se obtuvo una muestra de las siguientes 26 dependencias universitarias; Facultades de: Medicina, Odontología, Químico Farmacobiología, Psicología, Historia, Letras, Derecho, Bellas Artes, Economía, Contaduría, Veterinaria, Ing. Civil, Filosofía, Ing. Mecánica, Ing. Química, Ing. Eléctrica, Ing. en Tecnología de la Madera, Arquitectura, Biología, Físico Matemáticas. Escuela de Enfermería, Institutos de: Ingeniería Mecánica, Investigaciones sobre Recursos Naturales e Investigaciones Agropecuarias y Forestales.

Los sectores estudiados fueron: autoridades, académicos, administrativos y estudiantes inscritos al 2017. La muestra se obtuvo de la base de datos proporcionada por la Dirección de Personal y la Dirección de Servicios Escolares de la UMSNH. El tamaño de muestra se obtuvo a partir de la formula, (Tabla 1), (valores para la muestra, Z=1.96; p= 0.5; q=0.5; E = 0.05). En tanto que la muestra efectiva, consiste el número de entrevistas obtenido, que mantienen un nivel de significancia y representatividad aceptable.

Tabla 1 | *Universo, población y muestra de estudio*

Universos	*Población*	*Tamaño mínimo de muestra*	*Muestra efectiva*	*Valor de Z*
Autoridades	130	26	16	12% del total*
Docentes	2,445	332	226	1.60
Estudiantes	36,121	380	383	1.96
Administrativos	799	259	205	1.65
Total de la Población	39,495	991	705	

**Para poblaciones pequeñas se obtuvo una muestra ligeramente superior a 10% de la población.*
Fuente: Elaboración propia con base en la Dirección de Personal y la Dirección de Servicios Escolares de la UMSNH, 2017.

4.1 VARIABLES Y DISEÑO DE LA ENCUESTA

A partir del estudio y el análisis de las variables e indicadores para la RSU empleados en otros estudios (ARANGO et al., 2014; AUSJAL, 2009; CANTÚ, 2013; GASCA; OLVERA, 2011; IESALC, 2008; IZARRA, 2019; LIMO; PEÑA, 2019; RAMOS et al., 2016; VALLAEYS; CARRIZO, 2006), la RSU en la UMSNH, comprende cinco ámbitos: ambiental, organizacional, educativo, social y conocimiento. Las variables empleadas fueron: Manejo de recursos Ambientales (MRA) (cuatro indicadores); Gestión Organizacional (GO) (cuatro indicadores); Gestión y Producción de Conocimiento para la RSU (GPC) (tres indicadores); Formación para la Responsabilidad Social (FRS) (cuatro indicadores) y Proyección Social de la Universidad (PSU) (dos indicadores). (Tabla 2).

Para la recolección de datos se empleó un cuestionario por entrevista personal y el diseño establecido para la versión final del instrumento de medición, se integró en tres secciones: 1) folio, el universo y nombre de la investigación; 2) perfil de los encuestados, variando un poco según el universo del que se trata y 3) variables, indicadores, sus respectivos ítems y la escala de medición por intervalos (escala tipo Likert).

Para estimar la confiabilidad del cuestionario, se empleó coeficiente alfa de Cronbach (α) mostrando consistencia para los cuatro instrumentos de medición; en la prueba piloto. Los resultados de α fueron: excelente en docentes (0.943), administrativos (0.915) y estudiantes (0.927); y aceptable en autoridades (0.782) (BOJÓRQUEZ et al., 2013; GONZÁLEZ; PAZMIÑO, 2015). Una vez verificado el instrumento, se obtuvieron los datos en la aplicación de entrevistas presenciales por sectores: directivos (autoridades), docentes, administrativos y estudiantes, con un tiempo de respuesta entre 10 y 15 minutos.

4.2 EMPLEO DE LA TÉCNICA MÍNIMOS CUADRADOS PARCIALES (PARTIAL LEAST SQUARES, PLS)

La investigación se apoyó en la Modelación de Ecuaciones Estructurales (SEM) que permite realizar regresiones múltiples entre variables latentes (BARROSO; CEPEDA; ROLDÁN, 2005). Para desarrollar el proceso metodológico se las condiciones y aplicabilidad de las herramientas para análisis multivariable (LÉVY; VARELA, 2003), se decidió utilizar la modelación de *PLS,* que es más apropiado para la predicción de las variables, alta complejidad y desarrollo de teoría (análisis exploratorio) (CHIN, 2010), se maximiza la varianza de las variables dependientes explicadas por las independientes, en vez de reproducir la matriz de covarianzas empírica (HAENLEIN; KAPLAN, 2004). Además, debido a que el enfoque estima las variables latentes como combinaciones lineales de las medidas.

Dichos modelos identifican la forma en que factores internos y externos afectan a las variables analizadas, considerando la forma en la que estas variables pudieran estar interrelacionadas. El PLS asume que cada constructo juega el papel de un concepto teórico que es representado por indicadores, y las relaciones entre constructos deben ser establecidas tomando en cuenta el conocimiento previo (teoría) del fenómeno bajo análisis (LOEHLIN, 1987). El PLS se basa en un algoritmo iterativo y los parámetros son calculados por regresiones *Least Squares.* El término *Partial* se debe a que el procedimiento iterativo involucra separar los parámetros en vez de estimarlos de forma simultánea (BATISTA-FOGUET; COENDERS, 2000; HAENLEIN; KAPLAN, 2004; ROLDÁN; SÁNCHEZ-FRANCO, 2012).

Con los resultados obtenidos, se construye un modelo que permita ver las interrelaciones entre las variables de la RSU, enfocándose en maximizar la varianza Los resultados identifican los factores que más impactan a cada uno de los índices, con lo cual, se apoyaría a la toma de decisión al conocer el impacto por variable.

4.3 VARIABLES LATENTES Y OBSERVADAS

Uno de los conceptos más relevantes para *SEM* es el de variables latentes. Éstas no son directamente observables o medidas por un instrumento generalmente aceptado (SCHUMACKER; LOMAX, 2004). Las variables latentes se conforman con las variables manifiestas, variables observadas o indicadores. En la Modelación *Path* PLS las variables latentes serán obtenidas como una combinación lineal de su grupo de variables observadas (indicadores) (LOEHLIN, 1987). Se asume que cualquier medición será imperfecta, como lo muestran (HAENLEIN; KAPLAN, 2004), cada observación en el mundo real viene con un error en la medición, que se compone de dos partes: (a) error aleatorio (causado por el orden de los *ítems* en un cuestionario o sesgo del encuestado); y (b) error sistemático, debido a la varianza. Por ello, el valor observado de un ítem se constituye con: 1) el verdadero valor de la variable; 2) el error aleatorio y, 3) el error sistemático.

El PLS, provee un marco para analizar relaciones múltiples entre constructos. Se asume que cada constructo juega el papel de un concepto teórico que es representado por sus indicadores, y las relaciones entre constructos deben ser establecidas tomando en cuenta el conocimiento previo (teoría) del fenómeno bajo análisis. En resumen, el PLS puede ser una herramienta poderosa por las mínimas demandas de escalas de medición, tamaño de muestra, y distribuciones residuales (CHIN, 2010) Para desarrollar el proceso metodológico se elaboró el siguiente cuestionario con base en las variables, ver Tabla 2.

El resultado obtenido en los indicadores se incorporó por dimensión en el software PLS smart 3.0, agrupando por dimensiones y variables. Luego se sugiere una forma de relación entre variables, generando las variables latentes, con base en la relación esperada entre las mismas. El siguiente paso consiste en correr la iteracción en la relación propuesta, la aplicación realiza los cálculos hasta llegar a la convergencia o estabilidad en las variables. Luego de varias pruebas, la consistencia estadística indica la fiabilidad del modelo y su capacidad de interpretación en la modelación de las variables integradas por los grupos de indicadores.

Tabla 2 | Operacionalizacion de las Variables

Variables	*Dimensión*	*Indicadores*	*Clave*
Manejo de Recursos Ambientales (MRA)	Protección del Ecosistema	Conocimiento del Plan Ambiental Institucional (PAI)	PE
		Suficiencia de áreas verdes	PE2
		Cuidado y protección de áreas verdes	PE3
	Manejo de Residuos	Depósitos para separación de residuos sólidos	MRA1
		Conocimiento de la clasificación de residuos sólidos	MRA2
		Disposición correcta de residuos sólidos	MRA3
	Uso de la Energía	Uso eficiente de energía	UE1
		Generación de Energía	UE2
	Tratamiento y cuidado del agua	Eficiencia en el uso de agua	TCA1
		Cuidado del agua	TCA2
	Influencia en Comportamientos Ecológicos	Re-uso de papel	ICE1
		Conocimiento de la huella ecológica	ICE2
		Fomento de movilidad de bajo impacto	ICE3
		Reducción de desechables	ICE4
		Influencia del PAI en hábitos ecológicos	ICE5
		Uso eficiente del agua	ICE6
Gestión Organizacional (GO)	Identidad Nicolaita	Atención a población vulnerable	IN1
		Practica de principios de humanismo	IN2
	Ambiente Laboral	Ambiente de estudio	AL1
		Respecto a la diversidad	AL2
	Remuneración y Capacitación	Percepción de equidad	RC1
		Percepción salario/remuneración	RC2
		Capacitación en RSU	RC3
	Participación y Democracia	Percepción de valores democráticos	PD1
		Equidad de género	PD2
Formación para la Responsabilidad Social (FRS)	Capacitación para la RSU	Contenido ambiental en el plan de estudios	CRS1
		Capacitación en atención de contingencias	CRS2
	Formación Multidisciplinaria	Capacitación en proyectos sociales	FM1
	Formación Interinstitucional	Inclusión en proyectos universitarios	FI1
		Participación en proyectos con otras organizaciones	FI2
	Formación de Reflexión Critica	Sensibilización ante problemas sociales	FR1
		Papel de la profesión en la sociedad	FR2
		Percepción de realización	FR3
Proyección Social de la Universidad (PSU)	Extensión	Vinculación con campañas ambientales	EX1
		Participación en campañas de concientización ambiental	EX2
	Vinculación	Vinculación con sectores marginados	VN1
		Bolsa de trabajo de la Universidad	VN2

Variables	Dimensión	Indicadores	Clave
Gestión y Producción de Conocimiento para la RSU (GPC)	Investigación Socialmente Útil y Pertinente	Investigación aplicada a grupos vulnerables	IP1
		Vinculación de la investigación en general	IP2
	Conocimiento Multidisciplinario	Proyectos de desarrollo con otros sectores	CM1
		Participación entre estudiantes y profesores en investigación	CM2
	Conocimiento para la Sustentabilidad	Fomento de conocimiento propio	CS1
		Investigación aplicada a mejorar la RSU	CS2

Fuente: Propuesta del Presente Estudio.

5 RESULTADOS

5.1 DESEMPEÑO DE LA RSU NICOLAITA

El desempeño de la RSU en la UMSNH, en escala con máximo de 5.0, para los directivos fue de un 3.57; para los docentes de un 3.25 y muy cercanos a 3.0; tanto administrativos como estudiantes. El promedio indica un desempeño regular. En términos de variables, la GO muestra el mejor desempeño (3.6) y la menor varianza (0.022), en tanto que el desempeño más bajo fue para para FRS y PSU, ambos con valor de 3.0. (Tabla 3). En la Tabla 4, se aprecia el desempeño global por sectores de la estadística paramétrica, en que se pueden observar las medidas de tendencia central y distribución, encontrando el desempeño más alto para AUT y el más bajo para AT, muy cercano con ET, así como la varianza más alta entre el sector docente (DT).

Tabla 3 | Desempeño Promedio de la RSU-UMSNH

	Administrativos (AT)	Docentes (DT)	Directivos (AUT)	Estudiantes (ET)	Prom.**	Varianza
MRA	2.99	3.02	3.35	3.08	3.111	0.027
GO	3.54	3.66	3.84	3.52	3.641	0.022
FRS	2.78	3.07	3.14	3.05	3.012	0.026
PSU	2.90	3.20	3.63	2.59	3.077	0.197
GPC	3.14	3.30	3.89	2.99	3.328	0.154
Promedio*	3.07	3.25	3.57	3.04		
Varianza	0.088	0.064	0.102	0.110		

**Promedio por sectores (grupos) a partir de los promedios por variable.*
***Promedio por variable a partir de los promedios por sector.*
Fuente: Elaboración propia con datos de campo.

Tabla 4 | Estadística descriptiva para el desempeño promedio global de la RSU.

	AT	AUT	DT	ET
Media*	3.089	3.545	3.225	3.128
Error típico	0.042	0.094	0.044	0.032
Mediana	3.073	3.586	3.214	3.150
Moda	2.805	3.857	3.238	3.125
Desviación estándar	0.605	0.374	0.656	0.624
Varianza de la muestra	0.366	0.140	0.430	0.390
Curtosis	-0.367	1.802	-0.665	-0.153

	AT	AUT	DT	ET
Coeficiente de asimetría	0.179	-1.254	0.090	-0.156
Rango	2.951	1.429	2.857	3.625
Mínimo	1.83	2.57	1.86	1.30
Máximo	4.78	4.00	4.71	4.93
Suma	633.27	56.71	728.93	1198.18
Obsevaciones (n)	205	16	226	383

** Promedio a partir del concentrado de información.*
Fuente: Elaboración propia con datos de campo.

5.2 MODELO PLS-SEM PARA EL DESEMPEÑO DE LA RSU NICOLAITA

Se siguió un proceso de tres pasos para la utilización del PLS: 1) los pesos de las relaciones, que vinculan los indicadores a sus respectivas variables latentes y son estimados; 2) se calculan los *case values* para cada variable latente basado en un promedio ponderado de sus indicadores; 3) estos *case values* son usados en un grupo de ecuaciones de regresión para determinar los parámetros de los coeficientes *paths* o estructurales (HAENLEIN; KAPLAN, 2004). El algoritmo regresa nuevamente a las relaciones del modelo de medición donde nuevos pesos (*outer weights*) son calculados, y el proceso continúa iterativamente hasta que se alcanza la convergencia de los pesos, ver Figura 1.

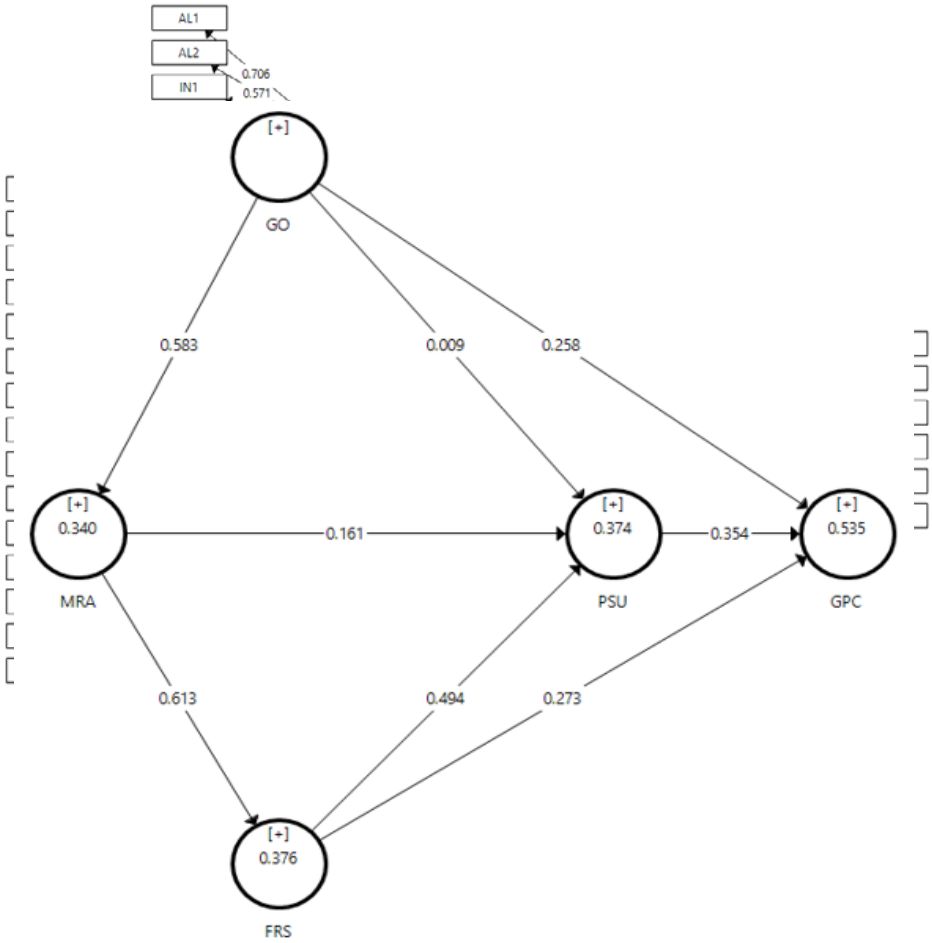

Figura 2 – Modelo de Variables de la Responsabilidad Social Universitaria
Fuente: Elaboración propia en Smart PLS, V. 3.0, con base en la información de campo.

En la Figura 1, se aprecia el modelo estructural en forma gráfica y representa las relaciones entre constructos que son hipotetizadas en el modelo propuesto. Para analizar el modelo estructural con *PLS*, éste debe ser planteado como un modelo recursivo, lo que significa que no se permiten *loops* en las relaciones estructurales. Debido a que el objetivo primario del *PLS* es la predicción, la bondad del modelo es evaluada por dos índices principales: los coeficientes de los *paths* estructurales y la predictividad combinada (R^2) de los constructos endógenos (CHIN, 2010). Duarte y Raposo (2010) utilizaron el criterio que la varianza explicada (R^2) para las variables endógenas debe ser mayor que 0.1.

En la Figura 2, se describe la evaluación de los coeficientes de sendero, estos coeficientes tienen valores estandarizados aproximadamente entre -1 y +1. Los coeficientes más cercanos a +1 indican una fuerte relación positiva, viceversa para -1, mientras que los coeficientes cercanos a 0 indican una debilidad y no son significativos. En la Tabla 5 se describe las relaciones que existen entre los constructos, con base en los coeficientes del sendero, que representan las relaciones hipotetizadas entre los constructos. Se aprecia que la relación más significativa es la variable MRA (0.583) con la variable FRS (0.613) y la relación menos significativa es la de GO con la variable PSU (0.009).

Tabla 5 | Coeficientes de Senderos

	FRS	*GO*	*GPC*	*MRA*	*PSU*
FRS			0.273		0.494
GO			0.258	0.583	0.009
GPC					
MRA	0.613				0.161
PSU			0.354		

Fuente: Elaboración propia con base en la información obtenida del trabajo de campo. Procesamiento del datos en Smart PLS, V. 3.0.

El coeficiente de determinación (R^2) es el más utilizado para evaluar un modelo estructural y es una medida de capacidad predictiva del modelo. Este se calcula como el cuadrado de la correlación entre un constructo endógeno y los valores predichos. De esta manera, representa la cantidad de varianza en el constructo endógeno explicado por todos los constructos endógenos vinculados a él. Los valores de R^2 están en un rango de 0 a 1, con niveles cercanos a la unidad R^2, indica un mayor nivel de precisión predictiva.

En la Tabla 6, se describe que la variable GPC para RSU, es la que presenta los indicadores más altos, el R^2 por 0.535 y el R^{2aj} 0.533, también se pueden ver de manera gráfica en las Figuras 1 y 2. En la Tabla 6 es posible apreciar que tanto el coeficiente Alfa de Cronbach y la medida de Fiabilidad Compuesta son superiores a 0.70 por lo que cada uno de los constructos muestran validez y consistencia interna. En relación a la Varianza Extraída Media, dos variables muestran un valor mayor a 0.53, PSU con 0.675 y MRA con 0.252. Los resultados arrojan que el Modelo Estructural muestra constructos robustos, ya que los niveles de validez son aceptables y dan alta fiabilidad a los valores que obtuvieron las variables latentes con base en las variables observables.

Tabla 6 | Fiabilidad, Validez de Constructo y Determinación (R^2)

Variables	*Alfa de Cronbach*	*rho_A*	*Fiabilidad compuesta*	*Varianza extraída media (AVE)*	*R^2*	*$R^{2\ Ajustada}$*
FRS	0.788	0.805	0.843	0.408	0.376	0.375
GO	0.778	0.802	0.837	0.398	--	--
GPC	0.853	0.856	0.891	0.578	0.535	0.533
MRA	0.786	0.789	0.833	0.252	0.340	0.339
PSU	0.838	0.843	0.892	0.675	0.374	0.372

Fuente: Elaboración propia con base en la información obtenida del trabajo de campo. Procesamiento del datos en Smart PLS, V. 3.0.

Al efectuar el proceso de cada uno de los indicadores mediante la técnica del PLS-SEM, se muestran los factores que afectan a cada índice, considerando aquellos con efecto total mayor a 0.40, ver la Tabla 8 y la Figura 2. Con base en la información anterior se obtuvo la correlación de variables latentes (Tabla 7) y se agruparon los índices resultando las variables como se observan en la Tabla 8. En que se observa que la Variable GPC para la RSU como la más significativa, ya que presenta una asociación positiva con cada una de las variables independientes MRA, GO y FRS.

Tabla 7 | Correlación de Variables Latentes.

Variables	*I*	*II*	*III*	*IV*
I. FRS				
II. GO	0.582			
III. GPC	0.635	0.555		
IV. MRA	0.613	0.583	0.505	
V. PSU	0.598	0.390	0.618	0.469

Fuente: Elaboración propia con base en la información obtenida del trabajo de campo y utilizando el PLS.

Para la medida Heterotrait-Monotrait (HTMT) se encontraron valores para las relaciones entre las GPC con FRS 0.764, para la MRA y FRS fue de 0.761 y entre GPC y PSU fue de 0.734 (véase Tabla 9). Con estos valores se consideran que los indicadores que componente cada una de las variables planteadas cumplen con los criterios de validez discriminante.

Siguiendo el procedimiento de Hair *et al*. (2016) el primer paso es la evaluación de cualquier signo de colinealidad, para lo cual se utilizaron los valores VIF, representados en la Tabla 10. Los constructos FRS, GO PSU son predictores del constructo GPS, y todos los valores se encuentran por debajo de valor límite de 5, por lo que no existe Colinealidad entre los constructos y se puede proceder a la evaluación del modelo estructural.

Tabla 8 | Factores que Afectan por Variable e Índice Considerando (efecto total mayor a 0.40)

CLAVE	*FRS*	*GO*	*GPC*	*MRA*	*PSU*	*CLAVE*	*FRS*	*GO*	*GPC*	*MRA*	*PSU*
AL1		0.706				ICE5				0.513	
AL2		0.571				ICE6				0.538	
CM1			0.812			IN1		0.696			
CM2			0.716			IN2		0.53			
CRS1	0.619					IP1			0.764		
CRS2	0.707					IP2			0.799		
CS1			0.783			MRA1				0.573	
CS2			0.681			MRA2				0.556	
EX1					0.868	MRA3				0.56	
EX2					0.859	PD1		0.772			
FI1	0.636					PD2		0.692			
FI2	0.753					PE				0.403	
FM1	0.695					PE2				0.406	
FR1	0.682					PE3				0.535	
FR2	0.525					RC3		0.605			
FR3	0.434					TCA1				0.452	
ICE1				0.439		TCA2				0.498	
ICE2				0.503		UE1				0.569	
ICE3				0.466		VN1					0.825
ICE4				0.472		VN2					0.727

Fuente: Elaboración propia con base en la información obtenida del trabajo de campo y utilizando el PLS.

Tabla 9 | Resultados Prueba Heterotrait-Monotrait Ratio (HTMT)

Variables	*FRS*	*GO*	*GPC*
FRS			
GO	0.725		
GPC	0.764	0.664	
MRA	0.761	0.710	0.609
PSU	0.723	0.464	0.734

Fuente: Elaboración propia con base en la información obtenida del trabajo de campo y utilizando el PLS.

Tabla 10 | Valores VIF del Modelo Estructural

Variables	*FRS*	*GO*	*GPC*	*MRA*	*PSU*
FRS			2.002		1.825
GO			1.517	1.000	1.725
GPC					
MRA	1.000				1.829
PSU			1.563		

Fuente: Elaboración propia con base en la información obtenida del trabajo de campo y utilizando el PLS.

En cuanto a los efectos f^2, se buscan valores mayores a 0.02 para indicar que existe un efecto entre las variables latentes. En este caso se considera que las variables FRS con PSU es 0.214, GO con MRA es 0.514, MRA con FRS es 0.602, principalmente, ya que todas tienen valores superiores al 0.02, (véase Tabla 11).

Tabla 11 | Efecto f^2

Variables	*FRS*	*GO*	*GPC*	*MRA*	*PSU*
FRS			0.080		0.214
GO			0.094	0.514	
GPC					
MRA	0.602				0.023
PSU			0.173		

Fuente: Elaboración propia con base en la información obtenida del trabajo de campo y utilizando el PLS.

5.3 DISCUSIÓN DE RESULTADOS

Se presentó una investigación con un modelo que mostró validez, por tanto, los resultados son fiables para conocer lo que ocurre en la interacción de variables e indicadores de la RSU implementada en la UMSNH. La descripción estadística presenta un desempeño cuantificable y el modelo estructural es coherente con los resultados esperados de la percepción de los actores universitarios.

La RSU ha sido un instrumento de gestión para fomentar un cambio de cultura socio-ambiental y busca impactar en la sociedad. El presente trabajo, ha revisado la implementación de la RSU de la UMSNH evaluada desde la percepción de los actores en un período de cinco años. El desempeño promedio global fue regular, con valores cercanos a 3 de 5 puntos posibles. Lo que implica que en la percepción global de los actores nicolaitas, la RSU ha dado resultados más bien regulares, que buenos o excelentes.

Uno de los resultados relevantes se expuso en la Tabla 8, indicando el impacto que tuvo cada índice por variable. Por ejemplo, para FRS dos indicadores mostraron relevancia mayor: CRS2 y FR1, y relevancia significativa: FI1, FI2, FM1, FR2, FR3, CRS1. Esto resulta importante al momento de valorar los aspectos que debieran fortalecerse para mejorar la RSU y el tipo de efecto esperado.

Otro de los elementos que aportan información valiosa para la RSU es que tres variables son las que tienen mayor incidencia direccional sobre todo el modelo que son: FRS, GO y GPC, lo que puede ayudar a mejorar los resultados de la implementación de la RSU para impactar en MRA y PSU de manera más eficiente, lo que sugiere que, para tener mejores resultados en el desempeño de la RSU, la actuación en estas tres variables es fundamental; más aún la actuación en los indicadores de mayor influencia.

Los objetivos planteados sobre cuantificar el desempeño de las variables sobre la RSU y el impacto de cada variable en esta se aprecian en las relaciones entre los indicadores y las variables. A nivel de interacción de variables la GO impacta direccionalmente al MRA, ambas variables son operativas, es decir; altamente visibles en la práctica, lo que puede explicar la dirección e intensidad del impacto.

Uno de los indicadores más heterogéneos es la capacitación para la RSU, en el que la autoridad aparece alta y con una amplia diferencia con relación con administrativos y los docentes. También se aprecia que los sectores con mayor varianza fueron AUT y ET, lo que sugiere una percepción muy distinta de ambos sectores que puede denotar también un sesgo en las respuestas, dada su postura política. Lo que representa una de las debilidades del trabajo.

También destaca que la FRS tiene un impacto relativamente considerable en la PSU, debido a que se trata de la vinculación y la extensión universitaria con el entorno. A la vez la FRS impacta a la GPC, aunque en menor medida. Como es de esperarse la GPC recibe impacto directo por tres senderos con las variables PSU, FRS y GO; lo que se explicaría dado que el conocimiento generado presenta relación directa con: la formación académica, la política universitaria y la proyección de la universidad. En resumen, los senderos muestran relaciones esperadas, no obstante; los coeficientes bajos, indicarían el regular desempeño de la RSU.

El bajo valor para PSU, reflejaría la falta de vinculación con el exterior, situación no es aislada en las universidades de Iberoamérica que han implementado la RSU y mantienen como uno de sus principales retos las prácticas en diversos entornos sociales, relacionando sus políticas con los problemas de sus comunidades, (AYALA-RODRÍGUEZ *et al*., 2010). Esto implica considerar la Educación Superior un Bien Común, incorporando en su gobernanza a las partes interesadas, e incluyendo en su foco de acción no alejarse de su realidad inmediata, en la búsqueda de *ranking* internacional (MARTÍ-NOGUERA; LICANDRO; GAETE-QUEZADA, 2018).

Un aspecto pendiente en la exploración de los resultados, son las expectativas y el seguimiento de los patrones que inculca la RSU fuera de los recintos universitarios a los actores involucrados. Tal como muestran algunos estudios sobre la importancia que los egresados dan a la RSU en sus expectativas y en la influencia para adoptar comportamientos e inclusión de categorías y temáticas sobre ética, medio ambiente y desarrollo sostenible, (ESPITIA-CUBILLOS; MENESES-PORTELLA; HUERTAS-FORERO, 2020). De manera que los resultados muestran la interacción de las variables, en la perspectiva de los actores, pero aún queda pendiente complementar las percepciones desde las categorías temáticas; sobre todo para la comunidad académica.

También se debe destacar que la respuesta de las universidades a la actual crisis socio-ambiental, encuentra un bastión de apoyo conceptual y de acción en la RSU, que a su vez constituye un reto importante, debido a que toca fibras sensibles en distintas dimensiones del proceso que van desde la producción de conocimiento y el currículo "oculto", hasta los métodos de enseñanza y el contenido formal (ARANGO *et al*., 2014; CHIRINOS; PÉREZ, 2016; GASCA; OLVERA, 2011; NÚÑEZ, 2013; RODRÍGUEZ *et al*., 2020; VALLAEYS, 2013; YURÉN; GARCÍA; BRISEÑO, 2019). Como se pudo apreciar para el caso de estudio, el cambio de comportamientos es lento e implica estrategias que procuren sinergias para mejorar el desempeño, en principio en las principales variables (como GO), pero luego se debe insistir

en el abordaje de nuevos paradigmas empezando por el conocimiento y siguiendo por el ejemplo en la adopción de normas, no siempre populares en un principio.

Otro de los aspectos que explora la RSU es su función como eje vinculante con el entorno social que involucra una variedad de elementos desde consultoría y transferencia de tecnología (MARTÍNEZ DE CARRASQUERO *et al.*, 2008); y la RSU como innovación social (AGUIRRE; GÓNZALEZ, 2020); hasta el papel de la universidad como *stakeholder*, transmitiendo sus preocupaciones a todos sus ámbitos de influencia, no solo empleados, (profesores y administrativos) y estudiantes (clientes), sino también a los proveedores de bienes, materias, servicios y financiamiento (CONTRERAS; ANDRADE, 2012; GÓMEZ; NAVEIRA; BERNABEL, 2018). Se trata de un aspecto que gana importancia, pero que aún enfrenta barreras en su implementación integral. No obstante, en los sectores de involucramiento directo; (profesores, investigadores, autoridades y administrativos -empleados- y clientes -estudiantes-) hay una perspectiva prometedora y favorable.

6 CONCLUSIONES

La Política sobre la instalación de un modelo de gestión de la RSU cuenta con cinco años al momento de realizar el presente estudio y diez años desde que el Plan Ambiental Institucional (PAI) marcara el antecedente sobre gestión ambiental en la UMSNH. La RSU, va más allá de los planteamientos sobre gestión ambiental, abarcando ámbitos como principios de identidad, proyección social, estructura organizacional, democracia, libertad e igualdad de género. Pero el enfoque más importante es el papel que la universidad tiene en la sociedad. Cómo se pudo apreciar, se han tenido avances, pero aún es necesario continuar mejorando este aspecto.

El desempeño de la implementación de la RSU en la UMSNH fue regular, lo cual implica que aún hay áreas de oportunidad para atender y mejorar. Estas áreas se pueden apreciar en el análisis estructural. Como era de esperar, la GO resulta ser una variable clave en el comportamiento del modelo dado que impacta directamente a MRA y a GPC e indirectamente a FRS. A su vez, que el indicador más importante de la gestión fue el ambiente laboral. Lo que está inmerso en las sociedades y ecosistemas del conocimiento. A lo que las acciones que impacten esta variable (en particular el indicador AL1) tendrán un efecto importante en el comportamiento del modelo. Como área de oportunidad el AL2 queda pendiente para mejorar su atención.

Uno de los aportes de este trabajo fue analizar el desempeño de la RSU en la UMSNH, desde un Modelo *SEM-PLS,* relativamente novedoso. Los resultados han mostrado la relación existente entre las variables y comportamiento esperado de las mismas. Dicho modelo estuvo representado por los constructos de cinco variables y 17 indicadores.

Los resultados de las pruebas de Alfa de Cronbach y Fiabilidad Compuesta, establecieron que cada uno de los constructos mostraron validez y consistencia interna. La relación más significativa se presentó entre las variables: MRA con FRS (0.613) y la relación menos significativa es la de variable GO con la PSU (0.009). A partir del cálculo del Coeficiente de Determinación fue posible establecer GPC para la RSU, es la que presenta los indicadores más altos, el R^2 por 0.535 y el R^{2aj} 0.533.

Las variables MRA, FRS y GPC, mostraron los impactos más altos y mayor interacción en la RSU. En tanto que la PSU y la GO muestran áreas de oportunidad. En concreto, se pudo apreciar para cada indicador en la Figura 1, que resume el resultado del *PLS-SEM.*

Entre las limitantes del estudio y una línea de investigación pendiente, están la falta de representatividad de quienes no pertenecen directamente a la universidad, (egresados, profesionistas independientes, empresas, gobierno y sociedad civil). En este sentido, es probable la existencia del sesgo de respuesta de los actores participantes en la investigación.

El papel de las universidades hacia el desarrollo sustentable aún es un camino en construcción, sin embargo, los esfuerzos como las políticas de RSU, muestran elementos firmes de avance en el compromiso institucional. No obstante, aún falta generalizar estas medidas, así como interiorizarlas en las comunidades y que su impacto sea cada vez más notorio. Una vez analizada la RSU en la UMSNH, se ha demostrado cuáles variables deben ser influidas para procurar un mayor impacto positivo en la RSU. A la vez que se aprecian las diferencias entre las percepciones de los sectores universitarios, mismas que debieran ser consideradas en la estrategia de seguimiento de la RSU.

Los autores manifestamos no tener conflicto de interés al presentar los resultados de esta investigación.

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Impact evaluation based on benefit indicators (IEBBI): methodological proposal for agroecological farmers' markets

Evaluación del impacto basada en indicadores de beneficios (IEBBI): propuesta metodológica para mercados de productores agroecológicos

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doi:10.18472/SustDeb.v12n2.2021.36070

Received: 13/01/2021
Accepted: 09/06/2021

ARTICLE – VARIA

ABSTRACT

Farmers' markets represent a growing strategy for the generation of food sovereignty and sustainability; however, little is known about their impacts in economic, social and environmental terms. The objective of this research was to develop a framework that would allow determining that impact. The resulting methodological framework includes 20 indicators divided into seven groups: proximity, profitability, perceived benefits, areas of opportunity, economic impact, social impact, and environmental impact. This methodology was applied in one agroecological farmers' market in Mexico City. Among the results, the main benefits are linked to socioeconomic interaction, while environmental impact indicators are the least considered. This methodology can guide the design, implementation, comparison, and monitoring of this type of initiative in the medium and long term.

Keywords: Farmers' markets. Organic markets. Short food chains. Impact assessment method. Agroecology. Socio-environmental project. Mexico.

RESUMEN

Los mercados de productores son una creciente estrategia de generación de soberanía alimentaria y sustentabilidad; sin embargo, poco se conoce de los impactos que han generado en términos sociales, ambientales y económicos. El objetivo de esta investigación fue desarrollar un marco analítico que permitiera determinar dicho impacto. El marco metodológico resultante está compuesto por 20 indicadores distribuidos en siete grupos: indicadores de proximidad, rentabilidad, beneficios percibidos, áreas de oportunidad, impacto económico, impacto social e impacto ambiental. Esta propuesta metodológica fue puesta a prueba en un mercado de productores agroecológicos de la Ciudad de México. Entre los resultados más sobresalientes sobre los datos descriptivos se pudo observar que los principales beneficios se encuentran en indicadores de interacción socioeconómica, mientras que los indicadores de impacto ambiental son los menos considerados. La metodología que se propone puede constituir una guía para orientar la política pública en el diseño, puesta en marcha, comparación y monitoreo de este tipo de iniciativas a mediano y largo plazo.

Palabras Clave: *Mercado de productores. Mercados orgánicos. Cadenas cortas agroalimentarias. Método para la evaluación de impacto. Agroecológico. Iniciativa socioambiental. México.*

1 INTRODUCTION

Agroecological farmers' markets, also called "tianguis" or organic markets, have emerged as a response to different social, economic, and environmental factors, such as the exclusion of small producers, rising food prices, the ecological footprint, soil deterioration, concerns about healthy food, and others related to the sustainability of agri-food systems (STAGL, 2002). Agroecological farmer's markets are also one of several forms of short food marketing chains, among which are also direct sales in the production unit or outside it, urban agriculture, and self-consumption agriculture (SCHMUTZ *et al*., 2017). It is worth mentioning that agroecological markets differ from conventional markets in several aspects, some of which are shown in Table 1.

Table 1 | Differentiating characteristics between farmers' markets

Differentiator	*Conventional Markets*	*Agroecological Markets*
Objective	Satisfy food demand.	Promote the consumption of agro-ecological products and solidarity economies.
Participants	Traders or intermediaries.	Direct producers and distributors, or short supply chains.
Products	Undifferentiated.	Produced through agroecological practices.
Origin of products	Not characterized, mostly from supply centres.	Generally local and to a lesser extent national.
Consumers	Undifferentiated.	Consumers aware of the benefits of agroecological products.
Organization	Managed by local governments	Self-organized by producers and/or by NGOs.

Source: Own elaboration.

Since the late 1990s, more than 1,000 farmers' market initiatives have been reported in the USA (STAGL, 2002) and there are currently more than 8,700 (USDA, 2019). However, in Latin American countries their development has been much lower. For example, although in Mexico the first farmers' market (also called "tianguis", "tianguis orgánicos" or "tianguis agroecológicos" in the Mexican context) was formed in 1998 in Guadalajara (JIMÉNEZ CASTAÑEDA; BUSTAMANTE LARA, 2017), more than twenty years later there are only 40 initiatives (DOMINGUEZ, 2019) and there is no academic publication that proposes a scheme to determine and monitor their level of development.

Therefore, the objective of this research is to design and apply an impact evaluation framework for farmers' markets, which allows measuring the effect that farmers' markets generate concerning the benefits they offer under the Triple Bottom Line scheme (environmental, social, and economic) (ELKINGTON, 2004).

This paper presents a review of the academic literature on impact measurement in farmers' markets. Subsequently, the proposed Methodology of impact evaluation based on benefit indicators (IEBBI) is described. Next, the results of the application of this model in a farmers' market in Mexico City are presented. Finally, the results are discussed considering the implications for the promotion and development of farmers' markets in operational and public policy design aspects.

2 IMPACT ASSESSMENT ON FARMERS' MARKETS

2.1 IMPACT OBJECTIVES AND EXPECTED BENEFITS

According to Gamboa Delgado and Rodríguez Ramírez (2015), the impact evaluation of a program or project "refers to the final attributable results and focuses on the outcomes or changes produced with respect to its objectives, over a period of time". The same author mentions that the main interest of impact evaluation consists in establishing the difference between the results obtained with the project and the results that could have been obtained if the project had not been implemented. Considering that the changes produced by an initiative are systemic and that their determination is complex, the impact evaluation of farmers' markets consists of determining the impact objectives of these initiatives, identifying the indicators that correlate with the impact objectives, and verifying that the measurement of the indicators is feasible.

The impact objectives of farmers' markets revolve around the effects of direct producer-consumer linkages. The principles proposed by FAO (2016) include minimum intermediation, process and product quality assurance (good agri-environmental and hygienic practices), proximity and transparency between producers and consumers, primary participation of small-scale agricultural producers, and collaborative consumers. From these principles derive a series of expected direct benefits such as reduced consumer prices, increased profitability, more nutritious or fresher products. Emerging benefits are also expected (ROGERS, 2008), such as the generation of trust between producers and consumers, co-creation of value, non-formal education of consumers. Examples of the main benefits and their relationship with the expected Sustainable Development Goals (SDG) can be seen in Table 2.

Table 2 | Relationship between impact objectives and expected benefits in producer markets.

Impact objectives	*Expected benefits*	*SDG*
1. Low intermediation	Consumer price reduction Producer profit increment	8. Decent Work and Economic Growth 10. Reduced inequalities
2. Quality assurance	More nutritious products Fresher products	2. Zero hunger
3. Closeness and transparency	Carbon footprint reduction Promotion of local culture Informal education	4. Quality education
4. Small-scale producers	Increased quality of life Increased profitability of the production unit	3. Good health and well-being
5. Consumer's collaboration	Co-creation of value Greater bonding and support	17. Partnerships for the goals

Source: Own elaboration.

2.2 IDENTIFICATION OF INDICATORS AND IMPACT ASSESSMENT

A search in Scopus using the terms 'farmers' market' found 462 documents, which coincides with the body of literature reported by Figueroa-Rodríguez *et al*. (2019). However, when searching within that body of literature for the term 'impact assessment', no results were found. Therefore, the search was expanded to any type of report on the effect of farmers' markets, which yielded 116 publications of which there were 27 books or book chapters, and 88 articles. A full-text review of each of the publications identified a total of 23 publications, which are described below.

The identified literature began in 2002 with the work of Stagl (2002), although 10 articles were published in the last two years. In terms of origin, the majority (10) is based on the US experience, followed by the United Kingdom (6), and other countries such as Finland, China, Italy, Pakistan, Canada, New Zealand, and Spain (7). No publications from Latin American farmers' markets were identified. Most of these publications have used a mixed set of indicators (8), however, some have focused on economic (6), social interaction (5), environmental (2), and health (2) impacts.

The indicators that have been used in mixed evaluations have been very varied. Among them, we found articles where they make a distinction of social, economic, and environmental benefits, as in Schmutz *et al*. (2017) and Vittuari *et al*. (2017), but in others, they have focused on transportation reduction, the proximity of producers and consumers, impacts on farms, food equity, and human capital, among others. Eight articles were found that referred to impact assessment, but only one elaborated a comparative assessment (SCHMUTZ *et al*., 2017).

Economic indicators are the most frequently mentioned. We could classify them as benefits to the producer (ALI *et al*., 2017; JABLONSKI *et al*., 2016; SILVA *et al*., 2015), to the population (ALI *et al*., 2017; BECOT *et al*., 2018; THATCHER; SHARP, 2008), and in-market aspects (LARSEN; GILLILAND, 2009; MALAGON-ZALDUA; BEGIRISTAIN-ZUBILLAGA; ONEDERRA-ARAMENDI, 2018).

Social-type indicators refer to rootedness and integration (CHEN; SCOTT, 2014; ROY *et al*., 2017), but parameters such as historical context, civic activities, external supports, and social responsibility have also been addressed.

There is also a wide variety of indicators used in environmental matters. Among them are those linked to the productive unit, such as ecosystem services and soil erosion (HALE *et al*., 2014), and the environment in general, such as greenhouse gases and climate change (LARSEN; GILLILAND, 2009).

Finally, health-related indicators were regarding food sanitation (WRIGHT *et al*., 2015) and consumption of healthy products (JILCOTT PITTS *et al*., 2016). Although, as mentioned above, impacts on specific ailments have been analyzed.

2.3 EVALUATION METHODS

As mentioned above, no methods were identified for assessing the impacts of farmers' markets in a comprehensive manner; however, methods were found for certain elements. For example, the Rapid Assessment Market (RAM) developed by Lev *et al*. (2007) is based on an active research model to assess consumer perception. The Sticky Economic Evaluation Device (Seed) model developed by the MarketUmbrella (2005) and, according to Brown and Miller (2008), assesses supplier gross sales, external impact (consumer spending surveys), and anecdotal impact (interviews with shoppers, neighbours and community members). Another model was proposed by Schmutz *et al*. (2017), which is based on a participatory method and through which sustainability was evaluated in economic, environmental, and social terms by comparing five different models of short food supply chains (SFSCs) which were self-consumption urban agriculture, commercial urban agriculture, community-supported agriculture (CSA), direct sales in the production unit and direct sales outside the production unit.

On the economic side, the use of specific methods has been reported. The LM3 method is used to measure the local economic benefit of short marketing chains (THATCHER; SHARP, 2008). The Seed method, mentioned above, has been complemented with the Need (Neighborhood Exchange Evaluation Device) and Feed (Food Environment Evaluation Device) methods to assess the economic impact (MALAGON-ZALDUA *et al*., 2018). Input-output (IO) models have also been used to assess how public programs and policies that facilitate increased access to local food for low-income households can ripple through state economies (BECOT *et al*., 2018).

3. METHODOLOGICAL PROPOSAL

3.1 IEBBI MODEL

Following the review of the evaluation frameworks available for short supply chains, it was observed that no model would allow impact evaluation under Latin American conditions. Therefore, a proposal was made for variables that could be evaluated through the perception of producers as objectively as possible, and this was defined as *Impact Evaluation Based on Benefit Indicators* (IEBBI). This proposal includes variables related to proximity, profitability, qualitative benefits, as well as social, economic and environmental impacts. These indicators are summarized in Table 3 and described below.

Proximity indicators. One of the main characteristics that promote short marketing circuits is the increase in proximity between the producer and the consumer (REINA-USUGA *et al.*, 2018). In this sense, three indicators are considered: physical proximity between the place of production and the point of sale; commercial intermediation and social proximity. Both physical distance and social distance have been important elements of the drive for local markets, given that such distance is a factor in consumer alienation (RISKU-NORJA *et al*., 2008) and negative environmental impact (KEMP *et al*., 2010). Commercial intermediation is defined as the number of intermediaries or the number of instances that receive an economic benefit from marketing the product other than the one that carries out the production or manufacture. Social proximity is measured by the consumer's knowledge of the production unit and the activity with frequent customers.

Table 3 | Impact Evaluation Based on Benefit Indicators (IEBBI)

Type	*Indicator*	*Measurement*
Proximity indicators	Physical proximity	Distance between the place of production and the point of sale.
	Commercial intermediation	Number of intermediaries.
	Social proximity	Closeness in the commercial relationship.
Profitability indicators	Employment generation	Number of employments.
	Proportion of the income	Income from sustainable production.
	Satisfaction	Degree to which the producer is satisfied with the productive activity and the benefits received.
	Future investment	Level of interest shown to invest in productive activity.
	Production	Improvements in production and / or transformation
Indicators of perceived benefits	Commercialization	Improvements in merchandizing
	Income	Benefits in the generation and stability of income

Type	Indicator	Measurement
Indicators of areas of opportunity	Barriers to entry for producers	Difficulties attending the market.
	Barriers to entry for consumers	Difficulty buying.
	Improvement areas	Limitations to participate and grow.
Economic impact indicators	Income	Amount of income generated by sustainable productive activity.
	Employment	Number of jobs created.
	Qualitative impacts	Other positive effects difficult to quantify.
Social impact indicators	Collective	Benefits of networking with other producers.
	Social contributions	Sociocultural characteristics of productive activity
Environmental impact indicators	Agroecological production	Characteristics of the product and raw material.
	Environmental contributions	Environmental contributions of the enterprise.

Source: Own elaboration.

Profitability indicators. Profitability in a small-scale production unit is difficult to determine since it is common for small producers not to keep records and labour costs are not considered since it is a family business, to mention a few. Therefore, indicators of employment generation, proportion of income, satisfaction, and future investment are used, according to the perception of the producers. Similar to the intention of Schmutz *et al*. (2017) to measure long-term profitability.

Indicators of perceived benefits. Belonging to a farmers' market for more than one year has generated different benefits for producers. Those related to improvements in production or processing, marketing, and income variation or stability are explored. These variables could be considered within the economic impact indicators; however, the measurement is not based on the economic data, but on the perception itself.

Indicators of areas of opportunity. To investigate the areas where the proposal and operation of the farmers' market can be improved, questions aimed at identifying the barriers to entry for producers, the respective barriers for consumers and the areas for improvement according to the perception of the beneficiaries are included, since it is common for sustainable ventures to present barriers such as scepticism, and lack of knowledge, among others (BINDER, 2016). Likewise, the perception of producers is investigated to achieve a successful farmers' market.

Economic impact indicators. The amount of income generated, employment generation, and qualitative impacts according to the perception of the producers are considered.

Social impact indicators. Two indicators are evaluated: those derived from the linkage between producers and the social impacts of the venture, beyond those generated by the economic activity, such as philanthropic initiatives, cultural promotion, conservation of cultural capital, education, among others.

Environmental impact indicators. These include impacts generated directly by the agroecological method of production, which are the most widely reported in the literature (HALE *et al*., 2014; RISKU-NORJA *et al*., 2008; SIMONCINI, 2015), including ecosystem services and biodiversity. In addition, there are other contributions of the business model or form of production that present environmental benefits, such as the reduction of waste, the use of alternative energies, environmental education activities, among others.

3.2 DESIGN OF THE INSTRUMENT

Once the areas of evaluation were defined, in-depth interviews were conducted with producers to review the possibility that the variable could be measured, that the item could be understood, and that other relevant aspects to be considered were identified. Four in-depth interviews were conducted in November 2020.

The data collection instrument consists of a mixed questionnaire (37 closed-ended questions and 16 open-ended questions), with a total of 51 items, including 7 control items. The items are distributed to meet the standards of a self-administered questionnaire design (SCHWARZ, 2001).

4. RESULTS OF THE APPLICATION OF THE IEBBI MODEL IN A CASE STUDY

4.1 POPULATION AND SAMPLING

The population chosen for the case study was the "Producers' Market" of Mexico City (MP), which began activities in August 2017, promoted by the Mexico office of the Food and Agriculture Organization of the United Nations (FAO) and the Secretariat of Rural Development and Equity for Communities (Sederec). The objective of the MP is to *"generate a meeting space between local producers and urban consumers committed to their health, the protection of the environment and the strengthening of local economies, under the principles of fair trade, Short Agrifood Chains (CCA) and without intermediaries"* (FAO; SEDEREC, 2018).

However, due to the absence of producers, only 25 of the 34 registered producers (75%) were able to participate. Nevertheless, according to the coordinators, those that participated are the most consistent. Two questionnaires were not fully completed because the participant did not have all the information because he/she was not responsible for the enterprise.

4.2 PROFILE OF PRODUCERS' MARKET PARTICIPANTS

Of the producers representing each project, 13 (54%) are women and 11 are men. The age of the producers ranges from 26 to 64 years old. There is a particular concentration between 30 and 40 years of age, a range in which 30% of the producers are. However, 6 of them (25%) are over 60 years old.

The main educational level among the group of producers is the university, which 14 of them have (58%). Three representatives (13%) have a postgraduate degree. Adding the producer representatives who have a bachelor's or postgraduate degree as their highest level of education gives a total of 17 producers, which represents 70%. The distribution of men and women concerning educational level is very similar.

Most of the farmers earn a family income of between 5 and 10 thousand Mexcian Pesos. Only two farmers generate incomes of more than 20,000 pesos per month. No significant statistical difference was found when comparing income concerning gender, age groups, the maximum level of education. Although it is observed that people with primary and secondary education earn less than 10 thousand pesos. It was observed that 18 enterprises (78%) are family types and 5 (22%) are group initiatives. The majority (12, 52%) of the projects are between 3 and 10 years old, 4 projects are two years old or less and only 2 projects are more than 20 years old.

4.3 PROXIMITY INDICATORS

Physical proximity. All production units of the MP participants were found within a perimeter of fewer than 30 km. The average travel distance was 21 km (8.2 min and 32.5 max.) and 36 minutes (15 min and 63 max.) without considering vehicular traffic (Figure 1). However, 14 producers mentioned that given the traffic conditions it took them between 1 and 3 hours to reach the point of sale. Three producers obtain inputs from other states such as Veracruz, Oaxaca, and Querétaro.

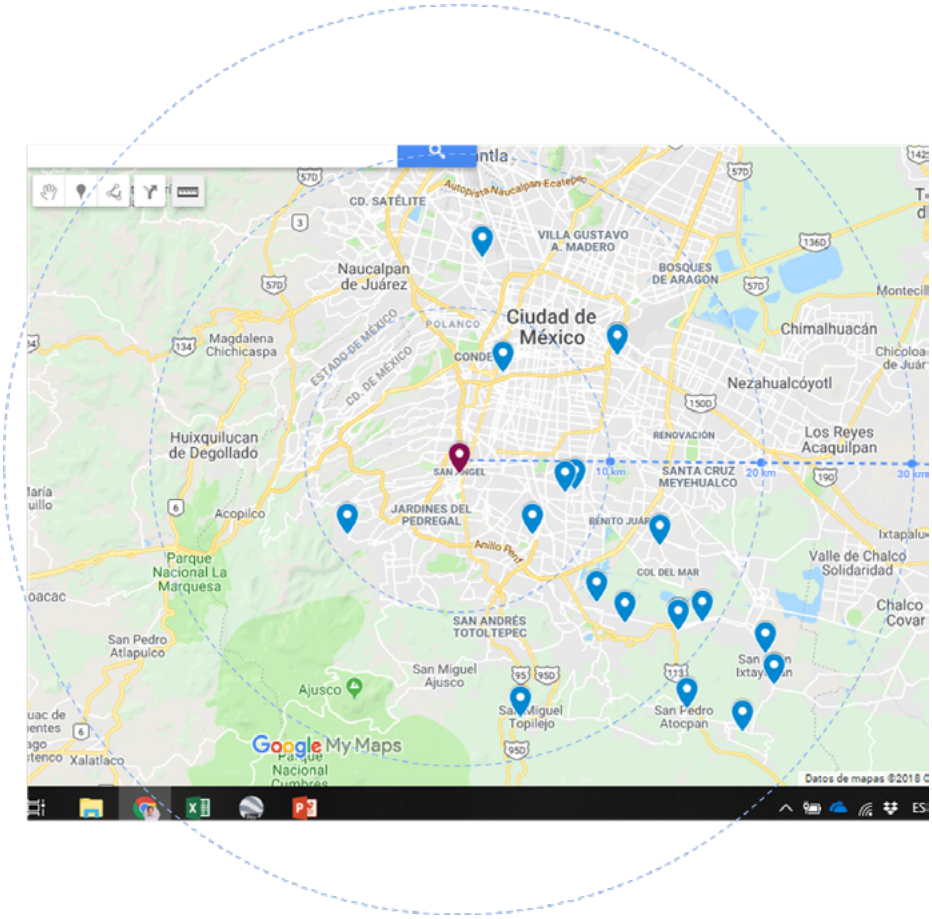

Figure 1 | The physical proximity of producers.

Source: Own elaboration with Google Maps technology.

Commercial intermediation. Producers have direct sales (70 points of sale); however, they also have a larger number of indirect sales (87 points of sale). Indirect sales outlets are mostly speciality stores and restaurants. The main source of income (more than 50% of income) for 11 producers comes from sales in the MP. For 4 of them, it represents 90% of income or more. On average, 80% of sales are made directly to the consumer. The remaining 20% is made indirectly (specialized stores 24%, hotels, restaurants, etc. 18%, intermediaries 19% and others 19%) (Figure 2).

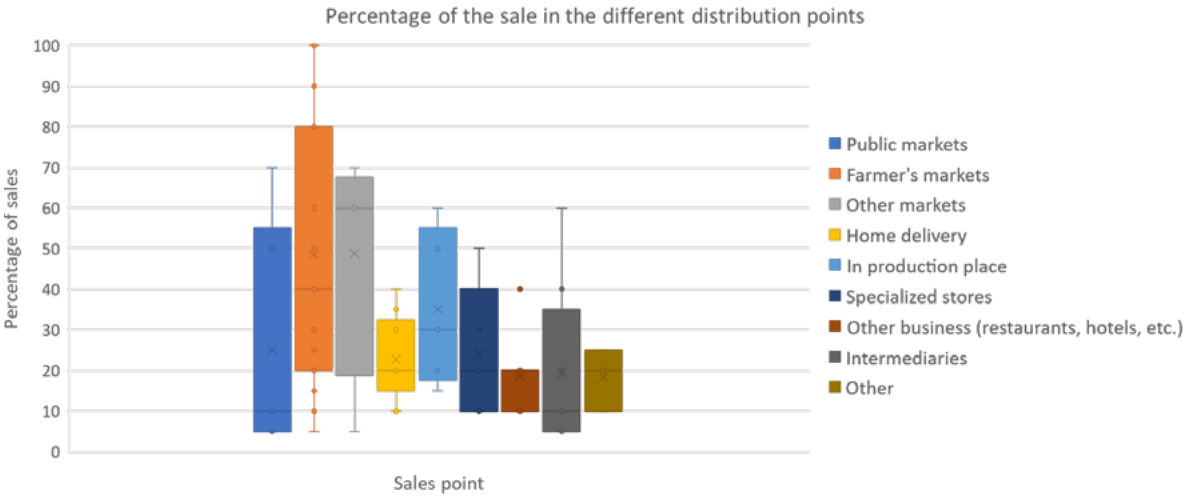

Figure 2 | Commercial intermediation.

Source: Own elaboration.

Social proximity. When asked about how many clients know the production unit and how many are interested in the producer, there was no clear trend (Figure 3.a and 3.b). The number of frequent clients per producer is between 11 and 20. nine producers mentioned that more than 15% of their sales comes from frequent clients (Figure 3.c). As for advance purchases, only 3 producers mentioned that more than 10 clients do so (Figure 3.d).

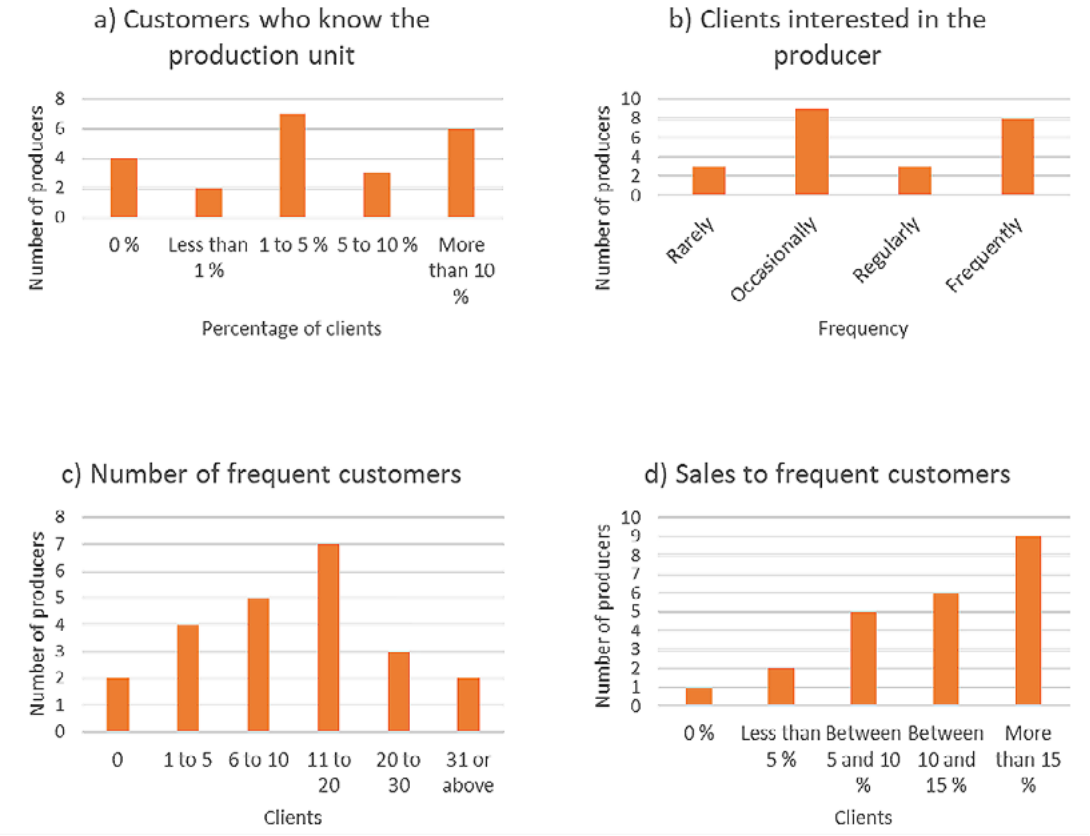

Figure 3 | Social proximity

Source: Own elaboration

4.4 PROFITABILITY INDICATORS

Employment generation. Participants in the Producers' Market generate 120 jobs, 70 are permanent and 50 are casual. Most of the jobs are generated by personal or family enterprises. Collective ventures have been founded for a shorter period. On average, each venture generates 3 permanent jobs, including its founders. Some ventures generate more than 10 casual jobs (Figure 4.a).

Proportion of income. Ten producers depend solely on sales of agroecological or sustainable products. Six producers depend less than 40% of their income on sustainable production. The majority (9 producers) earn between 5 and 10 thousand pesos and 9 producers generate 20 thousand pesos or more monthly (Figure 4.b).

Degree of satisfaction. Eight producers mentioned that they are close to reaching the desired sales volume. Fifteen producers mentioned being far from the desired level of sales. The benefits they obtain from productive activity, in addition to the economic one, were: having contact with clients (8), promoting or having a good quality of life (7), family integration and economic independence (2) and personal development (1) (Figure 4.c).

Investment required. Eleven producers mentioned that to continue developing their project they require an investment fewer than 30 thousand pesos and twelve require a larger investment. Most of the needs focused on machinery, tools and materials for marketing. The options that were not selected are wages, salaries and payments for services (Figure 4.d).

Projection to success. The answers to the question "What does it take to be successful?" revolved around aspects related to business development (dissemination, labelling, logistics, etc.), rather than productive aspects (inputs, production training, machinery, and tools).

Figure 4 | Profitability indicators

Source: Own elaboration

4.5 INDICATORS OF PERCEIVED BENEFITS

Production benefits. The main benefits in production were presented in the increment in the quantity produced, the improvement of the product's image and the increment in production know-how. The options referring to improvements in production processes and costs were not selected (Figure 5.a).

Marketing benefits. When asked about the main marketing improvement, producers mentioned that they have had better direct access to customers, an increased number of customers, and increased channels for distribution. Improved sales skills and reduced marketing costs were not selected (Figure 5.b).

Additional benefits. Most of the perceived benefit is focused on improved revenue stability. However, improvements in increased revenue and increased customers are similar. The least perceived benefit was observed in the improved unit price of products (Figure 5.c).

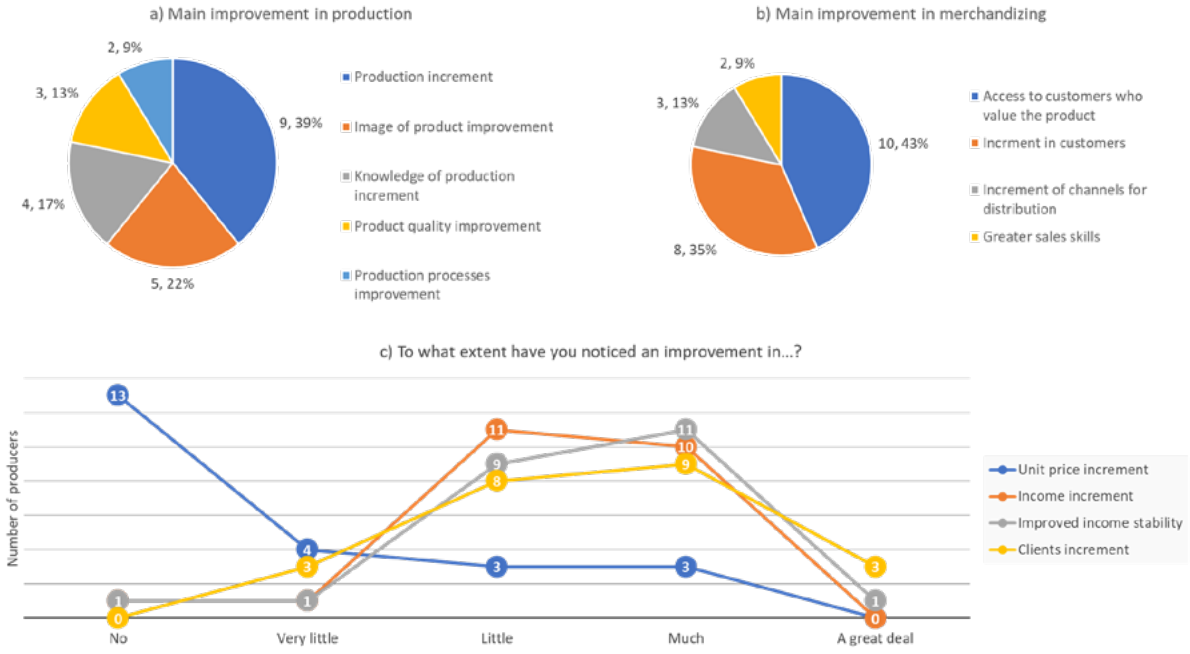

Figure 5 | Indicators of perceived benefits

Source: Own elaboration

4.6 INDICATORS OF AREAS OF OPPORTUNITY

Limitations to producer participation. The main barrier to entry reported is lack of transportation (52%), followed by lack of product quality (19%), too little income generated in the market (14%), lack of time (10%), and poor personal relationships with other members (5%).

Limitations to consumer participation. Sixty-one per cent of the producers said that the main barrier for consumers to attend was that they were not aware of the existence of the market, followed by lack of socio-environmental awareness (22%), distance from home (9%), lack of variety (4%), and lack of time to go to the market (4%). The only option not selected was the high prices compared to the conventional product.

Success factors of a PM. According to the producers, the main elements of success are dissemination, a fixed location, and the quality of the products. The honesty and participation of the producers and the leadership of the coordination were also mentioned.

4.7 ECONOMIC IMPACT INDICATORS

Income. Although the source of income of many of the farmers varies, the majority of the main source of income comes from the sale of agroecological or sustainable products. Of the 10 producers most dependent on the sale of these products, 2 generate less than 5 thousand pesos, one earns between 5, and 10 thousand pesos, one earns between 10 and 20 thousand pesos, 6 generate income of 20 thousand pesos or more per month.

Qualitative impacts. When producers were asked about other economic benefits, the responses revolved around facilitating linkages with clients (43%) and higher sales volumes (39%); the options of better income and higher sales occupied only 18%.

4.8 SOCIAL IMPACT INDICATORS

Guild participation. The main benefit of social interaction (22%), which could well be a commercial benefit, is that 5 producers exchange products among themselves for processing. The second perceived benefit is that other producers recommend the product (22%). Also, a similar number of producers mention that they have learned from other producers (22%) and that they are motivated by other producers (19%).

Social contribution. Most of the projects (15) have impacts related to the conservation of a cultural or traditional element, 9 projects benefit low-income people and 6 promote education for children (Table 4). None has records of such activities.

Table 4 | Social contribution

Impact	*Groups or organizations*	*Individual or familiar*	*Total*
Rescue or conservation of a local cultural or traditional product	5	10	15
Production in which low-income producers get benefits	2	7	9
Inclusive project of women, with different capacities and other minorities	1	3	4
Promotion of education in children (not environmental)		5	5
Promotion of adult training		3	3

Source: Own elaboration

4.9 ENVIRONMENTAL IMPACT INDICATORS

Agroecological production and supply. 21 producers process raw material directly. Only two producers obtain the raw material from conventional production, and this is because they have not found the agroecological option. Some producers have only one product, but some producers have more than 100 different products and presentations (Table 5).

Table 5 | Agroecological production

Offer	*All products are made from primary production*	*For some products, we buy supplies from agroecological producers*	*For most of the products we buy supplies from other agroecological producers*	*Most of the supplies come from conventional production*
Fresh food	5	5		
Processed foods	8	5	7	
Prepared food		2		
Arts or crafts	1			
For personal and home cleaning		1		1
Medicinal products	2			1
Supplies for agricultural or livestock production	1			
Educational or training products	4	1		
Ornamental plants			1	

Source: Own elaboration

Environmental contribution. Most of the projects (15) mentioned having impacts related to agroecological production: 4 projects have organic certification and 7 have other types of certification. Likewise, 7 projects carry out biodiversity conservation and 9 carry out pre-designed environmental education activities (Table 6). However, none of them quantifies impacts.

Table 6 | Environmental contribution

Impact	*Groups or organizations*	*Individual or familiar*	*Total*
Certified organic	1	3	4
Some other types of certification	1	6	7
Agroecological or natural	2	13	15
Zero waste generation	1	5	6
Soil restoration		6	6
Water collection and recycling	1	4	5
Carbon sequestration		1	1
Zero greenhouse gas emissions	1	3	4
Use of solar or wind energy		3	3
Conservation of biodiversity of plants or animals	1	6	7
Environmental education activities	2	7	9

Source: Own elaboration

5 DISCUSSION

5.1 RELEVANCE OF BENEFIT-BASED ASSESSMENT

In this article, rather than discussing the results obtained in this particular market, what is sought is to discuss the methodology employed. After the design work, several indicators were left out and may be important, such as those related to sanitation or health.

One of the main observations is regarding the relevance of the non-quantitative benefits that producers have had. After more than two years of operation, several of the producers mentioned that although the income and stability had improved a little, they was not what most motivated them to continue attending, since as identified by Charatsari *et al*. (2018) there are psychological or social factors that motivate participation. The aspect of having the opportunity to raise consumer awareness proved to be important. In this sense, evaluation elements should be oriented to social capital aspects. Environmental education activities can be one of these elements since, as studied by Schmit *et al*. (2017), such activities have an effect of increasing the flow of intellectual capital.

Another relevant indicator is the benefits that producers generate by linking and collaborating. In this research, it was observed that the linkage has allowed them to share client portfolios, give each other production recommendations and exchange products, and to a lesser extent, help each other overcome daily complications and give each other marketing recommendations. It has already been reported in the literature that farmers' markets can be a strategy for increasing social capital linked to food production (VOLPENTESTA; AMMIRATO; DELLA GALA, 2013). However, it seems that public promotion policies do not consider this element, most likely because of their difficulty of evaluation. In other words, limiting the evaluation of farmers' markets to economic aspects is a short-sighted view of the range of benefits.

It is important to discuss whether the direct linkage of the producer to the consumer provides increased social proximity. During this research, it is perceived that, despite physical proximity, social proximity in this market was low. This leads us to visualize that farmers' markets can have two different configurations. The first is where there is high social proximity, most likely derived from citizen management in which there is direct communication between producers and consumers as well as risk-sharing as mentioned by Stagl (2002) called community-supported agriculture (CSA). Secondly, there are initiatives in which there is no strong link between the producer and the consumer. As Chen and Scott (2014) demonstrated for consumer rootedness, social proximity can be an essential element of the success of a farmers' market, both in its growth and its permanence, and it is something that the promoters of these initiatives and public policy designers should consider. That is, thinking that generating a farmers' market consists only of convening producers and managing spaces, without considering citizen ownership (O'HARA; COLEMAN, 2017), can lead to these initiatives not acquiring sufficient strength, collapsing when external support runs out.

Another important aspect is that, even though producers observe that their activity has benefits for the environment, the consumer and for themselves, they do not have records that allow them to evidence them. This is particularly relevant concerning the promotion of farmers' markets. One of the main key factors of markets is the location (MORCKEL, 2018), and at least in Mexico, the availability of opening new spaces is limited since the opinion of officials and regulations do not allow new commercial spaces to be opened and less in areas with high pedestrian traffic, even when it is about contributing to sustainability. Therefore, if new spaces are to be opened or current ones improved for producers' markets, the benefits must be quantified and monitored, since, as mentioned by Ragona and Mazzocchi (2008), the lack of data makes it difficult to estimate the dynamics of regulation and the possibility of endogenous relationships, and therefore there are few elements to favour the creation of new markets.

5.2 LIMITATIONS AND FUTURE RESEARCH

One of the limitations of this research is that the evaluation model was applied to only one market. Therefore, it is necessary to extend the application of the model to more units and in longitudinal studies. A second limitation is that, as mentioned in the literature, farmers' markets have had different conceptions and varying growth histories in different countries, so it is to be expected that the evaluation frameworks need to be adapted depending on cultural conditions.

6 CONCLUSIONS

The promotion of agroecological farmers' markets is an important strategy to promote the Sustainable Development Goals and it is necessary to generate tools to demonstrate their success. This research fulfils the objective of designing and implementing an evaluation model for farmers' markets from the farmers' perspective. The method was designed to be replicable in other farmers' markets. The application is quick since it is a questionnaire that would be applied once a year (20 minutes per participant) and the results are easy to process, although the necessary modifications can be made depending on the objectives of each country or region.

Evaluation metrics should consider indicators of physical and social proximity, profitability, perceived benefits, areas of opportunity, economic impact, social impact and environmental impact. Likewise, consumer and producer health metrics can be included, as well as product health. The only thing to consider is that the number of indicators added may increase the length of the instrument and generate fatigue in the participants, which is why a review should be made before its application.

It is important to emphasize that the promoters of this type of initiative should observe the desired impact indicators and based on this, establish operational improvements. This will support the relevance of promoting farmers' markets, since currently, despite the environmental problems, there have been few achievements in terms of generating farmers' markets in Mexico.

ACKNOWLEDGEMENTS

To the participants and organizers of the Producers' Market who collaborated in the realization of this research.

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Evaluación del impacto basada en indicadores de beneficios (IEBBI): propuesta metodológica para mercados de productores agroecológicos

Impact evaluation based on benefit indicators (IEBBI): methodological proposal for agroecological farmers' markets

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doi:10.18472/SustDeb.v12n2.2021.36070

Received: 13/01/2021
Accepted: 09/06/2021

ARTICLE – VARIA

RESUMEN

Los mercados de productores son una creciente estrategia de generación de soberanía alimentaria y sustentabilidad; sin embargo, poco se conoce de los impactos que han generado en términos sociales, ambientales y económicos. El objetivo de esta investigación fue desarrollar un marco analítico que permitiera determinar dicho impacto. El marco metodológico resultante está compuesto por 20 indicadores distribuidos en siete grupos: indicadores de proximidad, rentabilidad, beneficios percibidos, áreas de oportunidad, impacto económico, impacto social e impacto ambiental. Esta propuesta metodológica fue puesta a prueba en un mercado de productores agroecológicos de la Ciudad de México. Entre los resultados más sobresalientes sobre los datos descriptivos se pudo observar que los principales beneficios se encuentran en indicadores de interacción socioeconómica, mientras que los indicadores de impacto ambiental son los menos considerados. La metodología que se propone puede constituir una guía para orientar la política pública en el diseño, puesta en marcha, comparación y monitoreo de este tipo de iniciativas a mediano y largo plazo.

Palabras clave: Mercado de productores. Mercados orgánicos. Cadenas cortas agroalimentarias. Método para la evaluación de impacto. Agroecológico. Iniciativa socioambiental. *México.*

ABSTRACT

Farmers' markets are a growing strategy for the generation of food sovereignty and sustainability; however, little is known about their impacts in economic, social and environmental terms. The objective of this research was to develop a framework that would allow to determine that impact. The resulting methodological framework includes 20 indicators divided into seven groups: proximity, profitability, perceived benefits, areas of opportunity, economic impact, social impact, and environmental impact. This methodology was applied in one agroecological farmers' market in Mexico City. Among the results, it could be observed that the main benefits are in socioeconomic interaction, while environmental

impact indicators are the least considered. This methodology can constitute a guide to the design, implementation, comparison, and monitoring of this type of initiatives in the medium and long term.

Keywords: Farmers' markets. Organic markets. Short food chains. Impact assessment method. Agroecology. Socio-environmental Project. Mexico.

1 INTRODUCCIÓN

Los mercados agroecológicos de productores, también llamados tianguis o mercados orgánicos, han surgido como una respuesta a diferentes factores sociales, económicos y ambientales, como son la exclusión de pequeños productores, el encarecimiento de los alimentos, la huella ecológica, el deterioro de los suelos, las preocupaciones por alimentos saludables y otros relacionados con la sustentabilidad de los sistemas agroalimentarios (STAGL, 2002). Asimismo, son una de las diversas formas de cadenas cortas de comercialización de alimentos, entre las cuales también están la venta directa en la unidad productiva o fuera de ella, la agricultura urbana y la agricultura de autoconsumo (SCHMUTZ *et al.*, 2017). Cabe mencionar que los mercados agroecológicos se diferencian de los mercados convencionales en diversos aspectos, algunos de ellos son mostrados en la Tabla 1.

Tabla 1 | Características diferenciadoras entre mercados de productores

Elemento diferenciador	*Mercados de productores convencionales*	*Mercados agroecológicos de productores*
Objetivo	Satisfacer la demanda de alimentos.	Promover el consumo de productos agroecológicos y las economías solidarias.
Participantes	Comercializadores o intermediarios.	Productores y distribuidores directos.
Tipos de productos	No diferenciados.	Provenientes de prácticas agroecológicas.
Procedencia de los productos	No caracterizada, proveniente en su mayoría de centrales de abasto.	Generalmente locales y en menor medida nacionales.
Características de los consumidores	No diferenciados.	Consumidores conscientes de los beneficios de productos agroecológicos.
Organización	Gestionados por gobiernos locales	Autoorganizados por los productores y/o por asociaciones civiles

Fuente: Elaboración propia.

Desde finales de la década de los 90, ya se reportaban más de 1,000 iniciativas de mercados de productores en EUA (STAGL, 2002) y actualmente hay más de 8 mil 700 (USDA, 2019). Sin embargo, en países latinoamericanos su desarrollo ha sido mucho menor. Por ejemplo, a pesar de que en México el primer mercado de productores (también llamados "tianguis", "tianguis orgánicos" o "tianguis agroecológicos" en el contexto Mexicano) se formó en 1998 en Guadalajara (JIMÉNEZ CASTAÑEDA; BUSTAMANTE LARA, 2017), a más de veinte años existen solo 40 iniciativas (DOMINGUEZ, 2019) y no hay ninguna publicación académica que proponga un esquema para determinar y monitorear su nivel de desarrollo.

Por ello, el objetivo de esta investigación es diseñar y aplicar un marco de evaluación de impacto para mercados de productores, el cual permita medir el efecto que los mercados de productores generan respecto a los beneficios que ofrecen bajo el esquema de la Triple Línea Base (ambiental, social y económico) (ELKINGTON, 2004).

En este documento se presenta una revisión de la literatura académica orientada a la medición de impactos en mercados de productores. Posteriormente, se describe el modelo propuesto de Evaluación de Impacto Basado en Indicadores de Beneficios o *Methodology of impact evaluation based on benefit indicators (IEBBI)*. En seguida, se exponen los resultados de la aplicación de este modelo en un mercado de productores de la Ciudad de México. Por último, se discuten los resultados considerando las implicaciones en la promoción y desarrollo de mercados de productores en aspectos operativos y de diseño de política pública.

2 LA EVALUACIÓN DE IMPACTO EN LOS MERCADOS DE PRODUCTORES

2.1 OBJETIVOS DE IMPACTO Y BENEFICIOS ESPERADOS

De acuerdo con Gamboa Delgado y Rodríguez Ramírez (2015) la evaluación de impacto de un programa o proyecto "se refiere a los resultados finales atribuibles y se enfoca en los desenlaces o cambios producidos respecto a sus objetivos, en un periodo de tiempo". El mismo autor menciona que el mayor interés de la evaluación de impacto consiste en establecer la diferencia entre los resultados obtenidos con el proyecto y los resultados que se podrían obtener si el proyecto no se hubiera implementado. Considerado que los cambios producidos por una iniciativa son sistémicos y que resulta compleja su determinación, la evaluación de impacto de los mercados de productores consiste en determinar los objetivos de impacto de dichas iniciativas, identificar los indicadores que se correlacionen con los objetivos de impacto, y comprobar que la medición de los indicadores es viable.

Los objetivos de impacto de los mercados de productores giran en torno a los efectos de la vinculación directa productor-consumidor. Los principios propuestos por la FAO (2016) incluyen: mínima intermediación, aseguramiento de la calidad de procesos y productos (buenas prácticas agroambientales e higiénicas), cercanía y transparencia entre productores y consumidores, participación principal de productores agropecuarios de pequeña escala y consumidores colaborativos. De estos principios derivan una serie de beneficios directos esperados como son la reducción del precio al consumidor, el aumento de la utilidad, productos más nutritivos o frescos. Así también, se esperan beneficios emergentes (ROGERS, 2008), como es la generación de confianza entre productores y consumidores, la co-creación de valor, la educación no formal de los consumidores. Ejemplos de los principales beneficios y su relación con los Objetivos de Desarrollo Sostenible esperados se pueden observar en la Tabla 2.

Tabla 2 | Relación entre los objetivos de impacto y beneficios esperados en mercados de productores.

Objetivos de impacto	*Beneficios esperados*	*Relación con los ODS*
1. Mínima intermediación	Reducción del precio al consumidor Aumento de la utilidad del productor	8. Trabajo decente y crecimiento económico 10. Reducción de las desigualdades
2. Aseguramiento de la calidad	Productos más nutritivos Productos más frescos Prácticas agroecológicas	2. Hambre cero
3. Cercanía y transparencia	Reducción de la huella de carbono Promoción de cultura local Educación no formal	4. Educación de calidad
4. Pequeños productores	Aumento de la calidad de vida Aumento de la rentabilidad de la unidad de producción	3. Salud y bienestar
5. Colaboración de consumidores	Co-creación de valor Mayor vinculación y respaldo	17. Alianzas para el logro de los ODS

Fuente: Elaboración propia.

2.2 IDENTIFICACIÓN DE INDICADORES Y EVALUACIÓN DE IMPACTO

Al realizar una consulta en Scopus usando los términos 'mercado de productores' (farmers' market), se encontraron 462 documentos, lo cual coincide con el cúmulo de literatura reportado por Figueroa-Rodríguez *et al*. (2019). Sin embargo, al buscar dentro de ese conjunto de publicaciones por el término 'evaluación de impacto' (impact assessment) no se encontraron resultados. Por ello,

se amplió la búsqueda a cualquier tipo de reporte del efecto de los mercados de productores, lo cual dio un resultado de 116 publicaciones de las cuales había 27 libros o capítulos de libros y 88 artículos. Al revisar en el texto completo cada una de las publicaciones, se identificaron un total de 23 publicaciones, las cuales describen a continuación.

La literatura identificada inicia en el 2002 con el trabajo de Stagl (2002), aunque 10 artículos fueron publicados en los últimos dos años. En cuanto al origen, la mayoría (10) se basan en la experiencia de EUA, seguidos del Reino Unido (6) y de otros países como Finlandia, China, Italia, Pakistán, Canadá, Nueva Zelanda y España (7). No se identificaron publicaciones provenientes de mercados de productores en América Latina. En su mayoría, estas publicaciones han usado un conjunto mixto de indicadores (8), sin embargo, algunos se han enfocado en impactos económicos (6), de interacción social (5), ambientales (2) y de salud (2).

Los indicadores que se han usado en evaluaciones mixtas han sido muy variados. Entre ellos encontramos artículos en donde claramente hacen una distinción de beneficios sociales, económicos y ambientales, como en Schmutz *et al.* (2017) y Vittuari *et al.* (2017), pero en otras se han enfocado en la reducción del transporte, la proximidad de productores y consumidores, los impactos en las granjas, la equidad alimentaria y el capital humano, entre otros. Se encontraron ocho artículos que hacían referencia a la evaluación de impacto, pero solamente uno elaboró una evaluación comparativa (SCHMUTZ *et al.*, 2017).

Los indicadores de tipo social hacen referencia al arraigo y la integración (CHEN; SCOTT, 2014; ROY *et al.*, 2017), pero también se han abordado parámetros como el contexto histórico, actividades cívicas, apoyos externos y responsabilidad social.

Asimismo, existe una amplia variedad de indicadores usados en materia ambiental. Entre ellos se encuentran aquellos vinculados a la unidad productiva, como los servicios ecosistémicos y la erosión de suelos (HALE *et al.*, 2014), y al entorno en general, como gases de efecto invernadero y cambio climático (LARSEN; GILLILAND, 2009).

Por último, los indicadores relacionados con la salud fueron respecto a la sanidad de alimentos (WRIGHT *et al.*, 2015) y el consumo de productos saludables (JILCOTT PITTS *et al.*, 2016). Aunque, como ya mencionamos, se han analizado impactos en padecimientos específicos.

2.3 MÉTODOS DE EVALUACIÓN

Como se mencionó anteriormente, no se identificaron métodos para la evaluación de impactos de los mercados de productores de una forma integral, sin embargo, sí se encontraron métodos para ciertos elementos. Por ejemplo, el Rapid Assessment Market (RAM) desarrollado por Lev *et al.* (2007), se basa en un modelo de investigación activa para evaluar la percepción de los consumidores. El modelo Sticky Economic Evaluation Device (Seed) desarrollado por la organización MarketUmbrella (2005) y, de acuerdo con Brown y Miller (2008), evalúa las ventas brutas del proveedor, el impacto externo (encuestas de gasto del consumidor) y el impacto anecdótico (entrevistas con compradores, vecinos y miembros de la comunidad). Otro modelo fue el propuesto por Schmutz *et al.* (2017), se basa en un método participativo y mediante el cual se evaluó la sustentabilidad en términos económicos, ambientales y sociales al comparar cinco diferentes modelos de cadenas cortas de comercialización de alimentos (SFSCs, por sus siglas en inglés: 'short food supply chains') las cuales fueron agricultura urbana de autoconsumo, agricultura urbana comercial, agricultura apoyada por la comunidad (CSA, por sus siglas en inglés: 'community supported agricultura'), venta directa en la unidad productiva y venta directa fuera de la unidad productiva.

En el aspecto económico se encuentran reportadas el uso de métodos específicos. El método LM3 es usado para medir el beneficio económico local de cadenas cortas de comercialización (THATCHER; SHARP, 2008). El método Seed, mencionado anteriormente, ha sido complementado con los métodos Need (Neighborhood Exchange Evaluation Device) y Feed (Food Environment Evaluation Device) para evaluar el impacto económico (MALAGON-ZALDUA et al., 2018). También han sido utilizados modelos de entrada y salida (IO) para evaluar cómo los programas y políticas públicas que facilitan un mayor acceso a los alimentos locales para los hogares de bajos ingresos pueden ondularse en las economías estatales (BECOT *et al.*, 2018).

3 PROPUESTA METODOLÓGICA

3.1 MODELO IEBBI

Posterior a una revisión de los marcos de evaluación disponibles para cadenas cortas de comercialización se observó que no existía un modelo que permitiera la evaluación del impacto de acuerdo con las condiciones de América Latina. Por ello, se realizó una propuesta de variables que pudieran ser evaluadas mediante la percepción de los productores de la forma más objetiva posible, y se definió como *Evaluación de Impacto Basado en Indicadores de Beneficios* (IEBBI). Esta propuesta incluye variables relacionadas con la proximidad, la rentabilidad, los beneficios cualitativos, así como impactos sociales, económicos y ambientales. Estos indicadores se resumen en la Tabla 3 y se describen a continuación

Indicadores de proximidad. Una de las principales características que promueven los circuitos cortos de comercialización es el incremento de la proximidad entre el productor y el consumidor (REINA-USUGA et al., 2018). En este sentido, se consideran tres indicadores: cercanía física entre el lugar de producción y el punto de venta; intermediación comercial y proximidad social. Tanto la distancia física como la distancia social han sido elementos importantes del impulso de los mercados locales, dado que dicha distancia es factor de la alienación de los consumidores (RISKU-NORJA et al., 2008) y del impacto ambiental negativo (KEMP et al., 2010). La intermediación comercial se define como el número de intermediarios o el número de instancias que reciben un beneficio económico por comercialización del producto diferente al que realiza la producción o manufactura. La proximidad social se mide con el conocimiento del consumidor sobre la unidad productiva y la actividad con clientes frecuentes.

Tabla 3 | Indicadores de evaluación de impacto de los mercados de productores

Tipo de indicador	*Indicador*	*Medición*
Indicadores de proximidad	Cercanía física	Distancia de la unidad productiva al punto de venta al consumidor final
	Intermediación comercial	Número de instancias que reciben un beneficio económico por comercialización del producto diferente al que realiza la producción o manufactura
	Proximidad social	Cercanía de la relación comercial entre el productor y el consumidor final
Indicadores de rentabilidad	Generación de empleos	Número de empleos generados
	Proporción en el ingreso	Ingreso que proviene de la actividad empresarial sustentable
	Satisfacción	Grado en el que el productor se encuentra satisfecho con la actividad productiva y los beneficios percibidos

Tipo de indicador	Indicador	Medición
	Inversión	Nivel de interés mostrado para invertir en la actividad productiva
Indicadores de beneficios percibidos	Producción o transformación	Mejoras en la producción y/o transformación
	Comercialización	Mejoras en la comercialización
	Ingresos	Beneficios en la generación y estabilidad de ingresos
Indicadores de áreas de oportunidad	Barreras de entrada de productores	Dificultad para participar
	Barreras de entrada de consumidores	Dificultad para asistir
	Áreas de mejora	Limitantes para participar y crecer
Indicadores de impacto económico	Ingresos	Cantidad de ingresos generados por la actividad productiva
	Empleos	Número de empleos generados
	Impactos cualitativos	Otros efectos positivos difícil de cuantificar
Indicadores de impacto social	Gremial	Beneficios de relacionarse con otros productores
	Aportación social	Características socioculturales de la actividad productiva
Indicadores de impacto ambiental	Producción agroecológica	Características del producto y la materia prima
	Aportaciones ambientales	Contribuciones ambientales del emprendimiento

Fuente: Elaboración propia.

Indicadores de rentabilidad. La rentabilidad en una unidad productiva de pequeña escala es difícil de determinar dado que es común que los pequeños productores no lleven registros y no se consideran costos de la mano de obra dado que es familiar, por mencionar algunos. Por ello, se usan indicadores de generación de empleos, proporción del ingreso, satisfacción e inversión futura, de acuerdo con la percepción de los productores. Similar a la intención de Schmutz *et al.* (2017) para medir la rentabilidad a largo plazo.

Indicadores de beneficios percibidos. Pertenecer a un mercado de productores a más de un año ha generado diferentes beneficios a los productores. Se exploran aquellos relacionados con las mejoras en la producción o transformación, la comercialización y la variación en el ingreso o su estabilidad. Estas variables pudieran considerarse dentro de los indicadores de impacto económico, sin embargo, la medición no se hace sobre el dato económico, sino sobre la percepción misma.

Indicadores de áreas de oportunidad. Con la intención de indagar las áreas en donde se puede mejorar la propuesta y operación del mercado de productores, se incluyen preguntas orientadas a identificar las barreras de entrada de productores, las respectivas de consumidores y las áreas de mejora de acuerdo a la percepción de los beneficiarios, ya que es común que los emprendimientos sustentables presenten barreras como el escepticismo y desconocimiento, entre otras (BINDER, 2016). Asimismo, se indaga sobre la percepción de los productores para lograr un mercado exitoso.

Indicadores de impacto económico. Se consideran la cantidad de ingresos generados, la generación de empleos e impactos cualitativos de acuerdo con la percepción de los productores.

Indicadores de impacto social. Se evalúan dos indicadores: aquellos derivados de la vinculación entre productores y los impactos sociales del emprendimiento, más allá de los generados por la actividad económica, como son iniciativas filantrópicas, de promoción cultural, conservación de capital cultural, educativas entre otras.

Indicadores de impacto ambiental. Se incluyen impactos generados directamente por el método agroecológico de producción, los cuales son los mayormente reportados en la literatura (HALE et al., 2014; RISKU-NORJA et al., 2008; SIMONCINI, 2015), dentro de los cuales están los servicios ecosistémicos y de biodiversidad. Además, existen otras aportaciones del modelo de negocio o forma de producción que presentan beneficios ambientales, como pueden ser la disminución de residuos, el uso de energías alternativas, las actividades de educación ambiental, entre otras.

3.2 DISEÑO DEL INSTRUMENTO

Una vez definidas las áreas de evaluación, se realizaron entrevistas a profundidad con productores para revisar la posibilidad de que la variable pudiera ser medida, que el ítem pudiera ser comprendido, y que se identificaran otros aspectos relevantes a ser considerados. En noviembre del 2020 se realizaron cuatro entrevistas a profundidad.

El instrumento de colecta de información consiste en un cuestionario mixto (37 preguntas cerradas y 16 preguntas abiertas), con un total de 51 reactivos, incluyendo 7 ítems de control. Los reactivos se distribuyen para cumplir con los estándares de un diseño de cuestionario autoadministrado (SCHWARZ, 2001).

4 RESULTADOS DE LA APLICACIÓN DEL MODELO IEBBI EN UN ESTUDIO DE CASO

4.1 POBLACIÓN Y MUESTREO

La población elegida para el estudio de caso fue el "Mercado de Productores" de la Ciudad de México (MP), el cual comenzó actividades en agosto del 2017, impulsado por la oficina en México de la Organización de las Naciones Unidas para la Alimentación y la Agricultura (FAO) y la Secretaría de Desarrollo Rural y Equidad para las Comunidades (Sederec). El objetivo del MP es el de "generar un espacio de encuentro entre productores locales y consumidores urbanos comprometidos con su salud, la protección del medio ambiente y el fortalecimiento de las economías locales, bajo los principios del comercio justo, de las Cadenas Cortas Agroalimentarias (CCA) y sin intermediarios"(FAO; SEDEREC, 2018). El muestreo fue de tipo censal procurando que todos los productores fueran incluidos, sin embargo, por la ausencia de productores, solo se logró la participación de 25 de los 34 productores registrados (75%). Sin embargo, estos productores son los más constantes de acuerdo con los coordinadores. Dos cuestionarios no se completaron del todo debido a que el participante no contaba con toda la información ya que no era el responsable del emprendimiento.

4.2 PERFIL DE LOS PARTICIPANTES EN EL MERCADO DE PRODUCTORES

De los productores representantes de cada proyecto, 13 (54%) son mujeres y 11 son hombres. La edad de los productores va de los 26 a los 64 años. Se tiene una concentración en particular entre los 30 y 40 años, intervalo en el que está el 30% de los productores. Sin embargo, 6 de ellos (25%) tienen más de 60 años.

El nivel educativo principal entre el grupo de productores es de universidad, el cual tienen 14 de ellos (58%). Tres representantes (13%) cuentan con posgrado. Sumando los productores representantes que cuentan con licenciatura o posgrado como nivel máximo de estudios da un total de 17 productores, lo cual representa el 70%. La distribución de hombres y mujeres respecto al nivel educativo es muy similar.

La mayoría de los productores perciben un ingreso familiar entre 5 y 10 mil pesos. Solo dos productores generan ingresos de más de 20 mil pesos mensuales. No se encontró diferencia estadística significativa al comparar ingresos con respecto género, grupos de edad, nivel máximo de estudios. Aunque se

observa que personas con primaria y secundaria perciben menos de 10 mil pesos. Se observó que 18 emprendimientos (78%) son de tipo familiar y 5 (22%) son iniciativas grupales. La mayoría (12, 52%) de los proyectos tienen entre 3 y 10 años de antigüedad, 4 proyectos tienen dos años o menos y solo 2 proyectos tienen más de veinte años.

4.3 INDICADORES DE PROXIMIDAD

Cercanía física. Todas las unidades de producción de los participantes en el MP se encontraron en un perímetro menor a los 30 km. La distancia de trayecto en promedio es de 21 km (8.2 min y 32.5 máx.) y de 36 minutos (15 min y 63 máx.) sin considerar el tráfico vehicular (Figura 1). Sin embargo, 14 productores mencionaron que dadas las condiciones de tránsito les tomaba entre 1 y 3 horas llegar el punto de venta. Tres productores obtienen insumos de otros estados como Veracruz, Oaxaca y Querétaro.

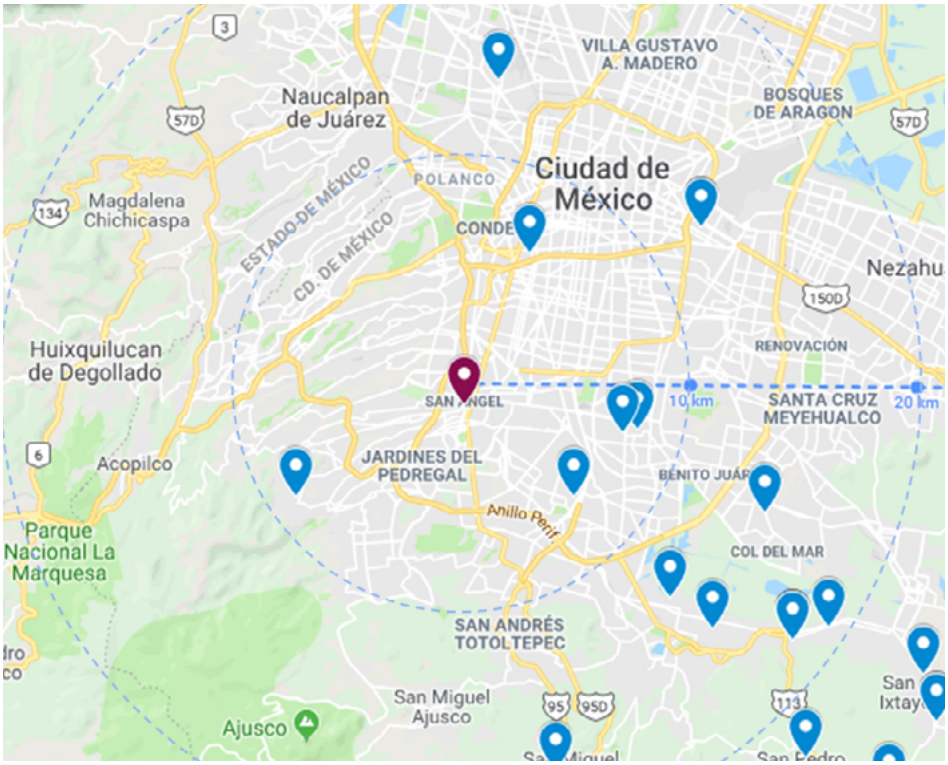

Figura 1 | *Proximidad física de los productores.*

Fuente: Elaboración propia con tecnología de Google Maps

Intermediación comercial. Los productores tienen una actividad dirigida hacia la venta directa (70 puntos de venta), sin embargo, también tienen una cantidad mayor en venta indirecta (87 puntos de venta). Los puntos de venta indirectos son en su mayoría tiendas especializadas y restaurantes. La principal fuente de ingreso (más del 50% del ingreso) para 11 productores proviene de las ventas en el MP. Para 4 de ellos representa el 90% del ingreso o más. En promedio, la venta que se hace de forma directa al consumidor es del 80%. El 20% restante se realiza de forma indirecta (tiendas especializadas 24%, hoteles, restaurantes, etc. 18%, intermediarios 19% y otros 19%) (Figura 2).

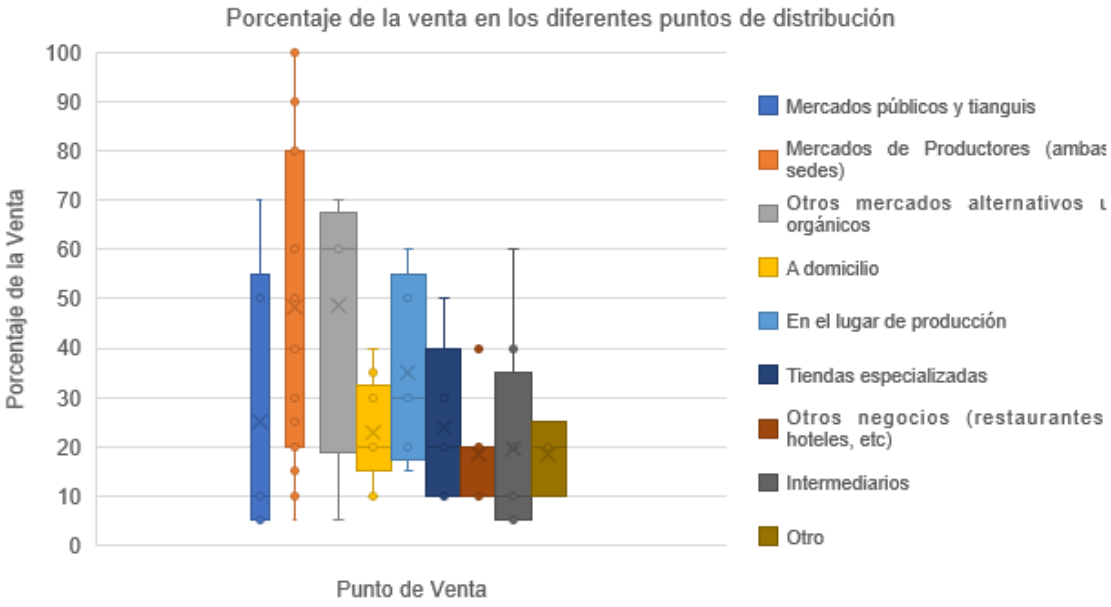

Figura 2 | Intermediación comercial.

Fuente: Elaboración propia

Proximidad social: Al preguntar sobre cuantos clientes conocen la unidad productiva y cuántos se interesan por el productor, no hubo una tendencia clara (Figura 3.a y 3.b). La cantidad de clientes frecuentes por productor es de entre de 11 a 20. Nueve productores mencionaron que más del 15% de su venta se destina a clientes frecuentes (Figura 3.c). En cuanto a compras por adelantado, solo 3 productores mencionaron que más de 10 clientes lo realizan (Figura 3.d).

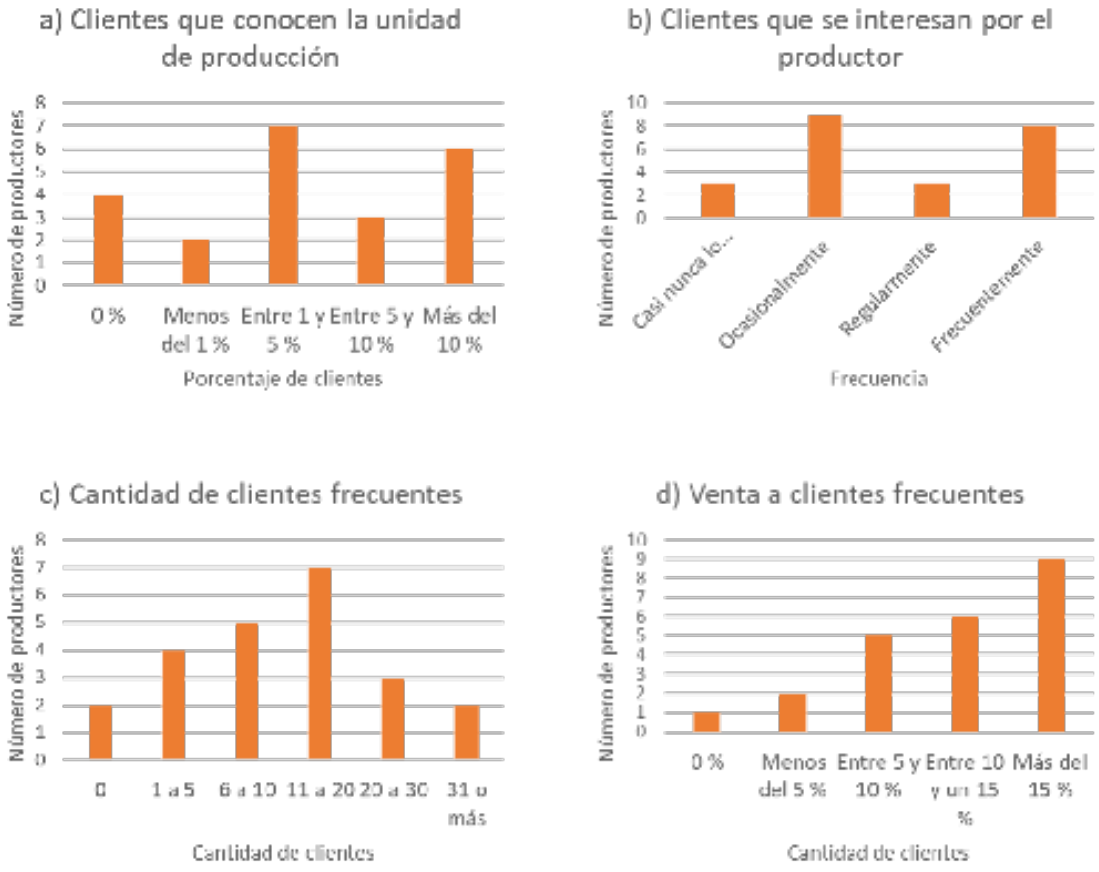

Figura 3 | Proximidad social

Fuente: Elaboración propia

4.4 INDICADORES DE RENTABILIDAD

Generación de empleos. Los participantes en el Mercado de Productores generan 120 empleos, 70 son permanentes y 50 son eventuales. La mayoría de los empleos son generados por los emprendimientos personales o familiares. Los emprendimientos colectivos tienen menos tiempo de haber sido fundados. En promedio, cada emprendimiento genera 3 empleos fijos, incluyendo sus fundadores. Algunos emprendimientos generan más de 10 empleos eventuales (Figura 4.a).

Proporción del ingreso. Diez productores dependen únicamente de las ventas de productos agroecológicos o sustentables. 6 productores dependen en menos del 40% de sus ingresos respecto a la producción sustentable. La mayoría (9 productores) perciben entre 5 y 10 mil pesos y 9 productores generan 20 mil pesos o más mensualmente (Figura 4.b).

Grado de satisfacción. Ocho productores mencionan que están cerca de alcanzar el volumen de ventas deseado. Quince productores mencionaron estar lejos del nivel de ventas deseado. Los beneficios que obtienen de la actividad productiva, además de la económica, fueron: tener contacto con clientes (8), promover o tener una buena calidad de vida (7), integración familiar e independencia económica (2) y desarrollo personal (1) (Figura 4.c).

Inversión necesaria. Once productores mencionaron que para seguir desarrollando su proyecto requieren una inversión menor a los 30 mil pesos y doce requieren una inversión mayor. La mayoría de las necesidades se centraron en maquinaria, herramientas y materiales para la comercialización. Las opciones que no fueron seleccionadas son: sueldos, salarios y pagos de servicios (Figura 4.d).

Proyección al éxito. Las repuestas a la pregunta "¿qué requiere para ser exitoso?" giraron en torno a aspectos que tienen que ver con un desarrollo empresarial (difusión, etiquetado, logística, etc.), más que a aspectos productivos (insumos, capacitación para la producción, maquinaria y herramientas).

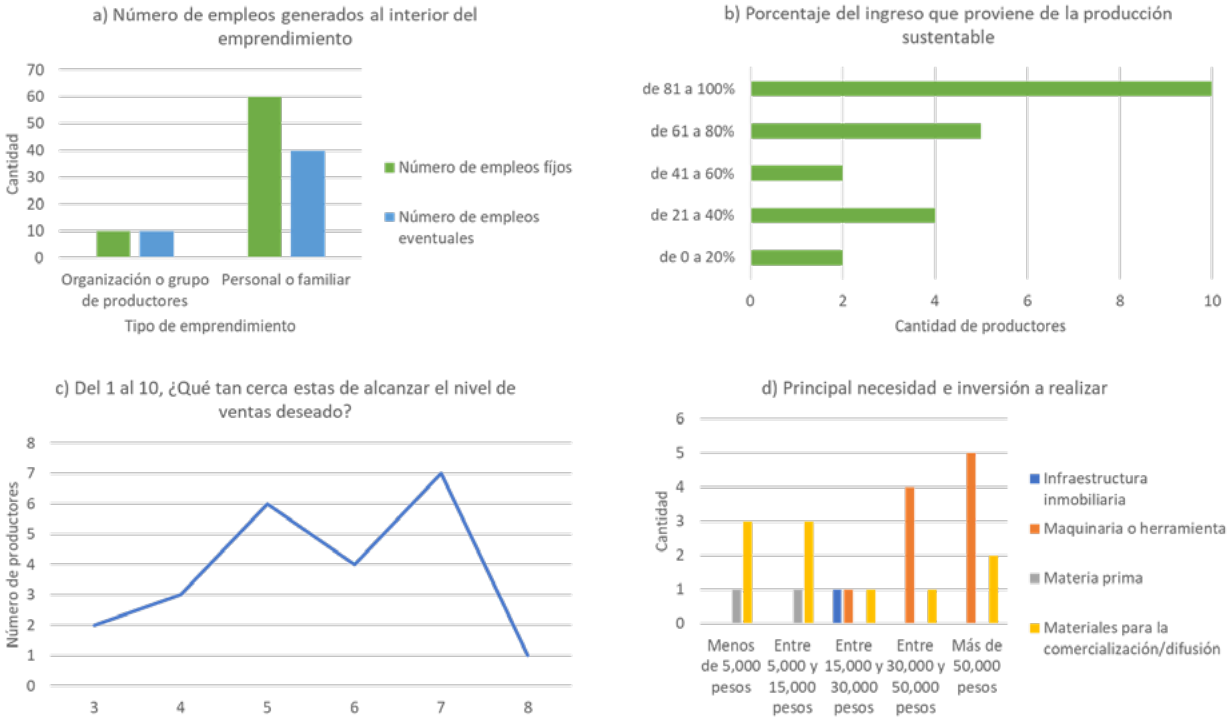

Figura 4 | Indicadores de rentabilidad

Fuente: Elaboración propia

4.5 INDICADORES DE BENEFICIOS PERCIBIDOS

Beneficios en la producción. Los principales beneficios en la producción se presentaron en el aumento de la cantidad producida, la mejora de la imagen del producto y el aumento de conocimientos para la producción. No fueron seleccionados las opciones referentes a mejoras en los procesos y costos de producción (Figura 5.a).

Beneficios en la comercialización. Al preguntar por la principal mejora en la comercialización, los productores mencionaron que han tenido mejo acceso directo a clientes, aumento de clientes y el aumento de canales para la distribución. No fueron seleccionadas las opciones de mejora de las habilidades para las ventas y la reducción de costos de comercialización (Figura 5.b).

Beneficios adicionales. La mayoría del beneficio percibido se centra en la mejora de la estabilidad del ingreso. Sin embargo, las mejoras en el aumento de ingreso y el aumento de clientes son similares. El menor beneficio percibido se observó en un mejor precio unitario de los productos (Figura 5.c).

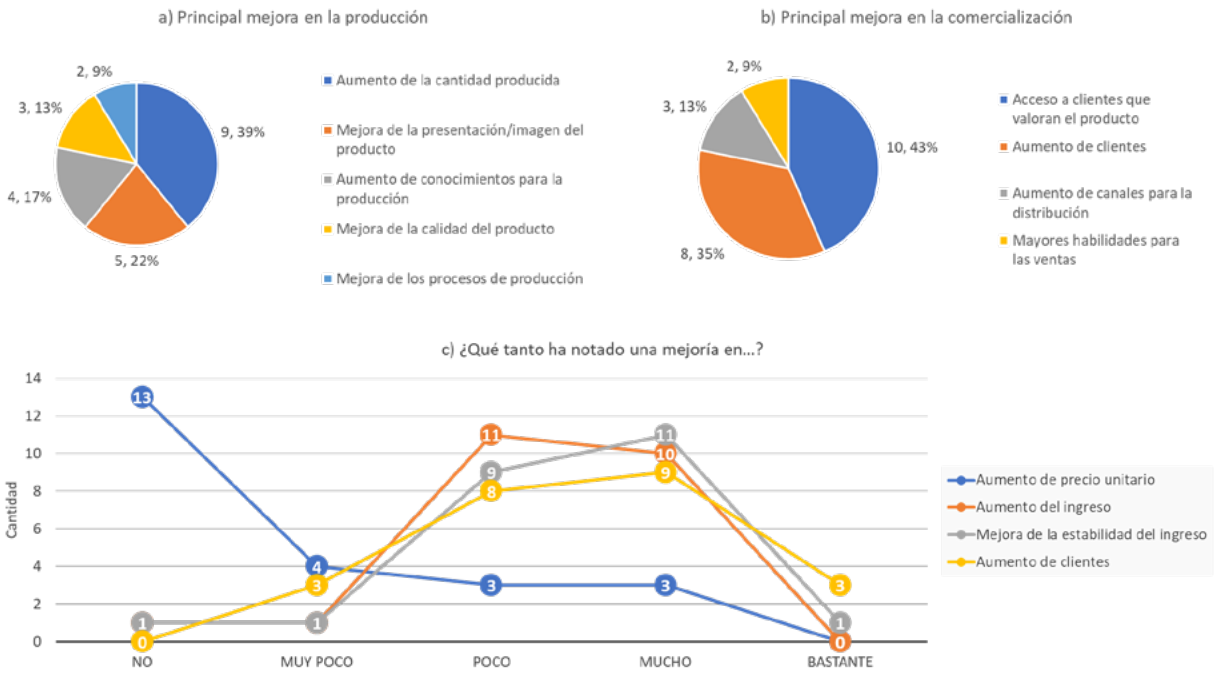

Figura 5 | Indicadores de beneficios percibidos

Fuente: Elaboración propia

4.6 INDICADORES DE ÁREAS DE OPORTUNIDAD

Limitantes de la participación de productores. La principal barrera de entrada reportada es la falta de transporte (52%), seguida de la falta de calidad del producto (19%), de que los ingresos que se generan en el mercado son muy pocos (14%), la falta de tiempo (10%) y malas relaciones personales con otros miembros (5%).

Limitantes de la participación de consumidores. El 61% de los productores opinó que la principal barrera que tienen los consumidores para asistir es que no conocen de la existencia del mercado, seguidos de la falta de conciencia socioambiental (22%), la lejanía con respecto al hogar (9%, poca variedad (4%)

y la falta de tiempo para ir al mercado (4%). La única opción no seleccionada, fue la referente a altos precios comparados con el producto convencional.

Factores de éxito de un MP. De acuerdo con los productores, los principales elementos de éxito son la difusión, un lugar fijo y la calidad de los productos. Asimismo, fueron mencionados la honestidad y participación de los productores y el liderazgo de la coordinación.

4.7 INDICADORES DE IMPACTO ECONÓMICO

Ingresos. Si bien la fuente de ingreso de muchos de los productores es variable, en su mayoría el principal proviene de la venta de productos agroecológicos o sustentables. De los 10 productores con mayor dependencia a la venta de estos productos 2 generan menos de 5 mil pesos, uno gana entre 5 y 10 mil, uno entre 10 y 20 mil pesos, 6 generan ingresos de 20 mil pesos o más al mes.

Impactos cualitativos. Al preguntar a los productores sobre otros beneficios económicos, las respuestas giraron en torno a la facilitación de la vinculación con clientes (43%) y mayores volúmenes de venta (39%) las opciones de mejor ingresos y mayores ventas ocuparon solo el 18%.

4.8 INDICADORES DE IMPACTO SOCIAL

Participación gremial. El principal beneficio de la interacción social (22%), que bien podría ser un beneficio comercial, consiste en que 5 productores intercambian producto entre ellos para su transformación. El segundo beneficio percibido es que otros productores recomienden el producto (22%). Asimismo, una cantidad similar de productores menciona que han aprendido de otros productores (22%) y que son motivados por otros productores (19%).

Contribución social. La mayoría de los proyectos (15) tienen impactos relativos a la conservación de un elemento cultural o tradicional, 9 proyectos benefician a personas de escasos recursos y 6 promueven la educación en niños (Tabla 4). Ninguno cuenta con registros de dichas actividades.

Tabla 4 | Contribución social

Impacto	*Organización o grupo*	*Personal o familiar*	*Total*
Rescate o conservación de un producto cultural o tradicional local	5	10	15
Producción en la cual se benefician productores de escasos recursos	2	7	9
Proyecto incluyente de mujeres, con capacidades diferentes y otras minorías	1	3	4
Fomento a la educación en niños (no ambientales)		5	5
Fomento a la capacitación en adultos		3	3

Fuente: Elaboración propia

4.9 INDICADORES DE IMPACTO AMBIENTAL

Producción agroecológica y oferta. 21 productores elaboran directamente la materia prima. Solo dos productores obtienen materia prima de la producción convencional y esto se debe a que no han encontrado la opción agroecológica. Existen productores que tienen solo un producto, pero también hay productores que tienen más de 100 diferentes productos y presentaciones (Tabla 5).

Tabla 5 | Producción agroecológica

Oferta	*Todos los productos los elaboramos desde la producción primaria*	*Para algunos productos compramos insumos de productores agroecológicos*	*Para la mayoría de los productos compramos insumos de otros productores agroecológicos*	*La mayoría de los insumos provienen de la producción convencional*
Alimentos frescos	5	5		
Alimentos procesados	8	5	7	
Comida preparada		2		
Artesanía o manualidad	1			
Para la limpieza personal y del hogar		1		1
Productos medicinales	2			1
Insumos para la producción agrícola o pecuaria	1			
Productos educativos o para la capacitación	4	1		
Plantas ornamentales			1	

Fuente: Elaboración propia

Contribución ambiental. La mayoría de los proyectos (15) mencionaron tener los impactos relativos a una producción agroecológica: 4 proyectos poseen certificación orgánica y 7 de otro tipo. Asimismo, 7 proyectos realizan conservación de biodiversidad y 9 realizan de forma prediseñada actividades de educación ambiental (Tabla 6). Sin embargo, ninguno realiza la cuantificación de impactos.

Tabla 6 | Contribución ambiental

Impacto	*Organización o grupo*	*Personal o familiar*	*Total*
Orgánica certificada	1	3	4
Algún otro tipo de certificación	1	6	7
Agroecológica o natural	2	13	15
Cero generación de residuos	1	5	6
Restauración de suelo		6	6
Captación y reciclaje de agua	1	4	5
Captación de carbono		1	1
Cero emisiones de gases de efecto invernadero	1	3	4
Uso de energía solar o eólica		3	3
Conservación de biodiversidad de plantas o animales	1	6	7
Actividades de educación ambiental	2	7	9

Fuente: Elaboración propia

5 DISCUSIÓN

5.1 RELEVANCIA DE LA EVALUACIÓN BASADA EN BENEFICIOS

En este artículo, más que discutir los resultados obtenidos en este mercado en particular, lo que se busca es discutir la metodología empleada. Después del trabajo de diseño, varios indicadores quedaron fuera y pueden ser importantes, como aquellos relacionados con la sanidad o la salud.

Una de las principales observaciones es respecto a la relevancia de los beneficios no cuantitativos que han tenido los productores. A más de un dos años de operación, varios de los productores mencionaron que si bien el ingreso y la estabilidad había mejorado poco, no eran lo que más les motivaban a seguir asistiendo, ya que como identificó Charatsari *et al.* (2018) existen factores psicológicos o sociales que motivan la participación. El aspecto de tener la oportunidad de sensibilizar a los consumidores resultó importante. En este sentido, los elementos de evaluación deben orientarse a aspectos de capital social. Las actividades de educación ambiental pueden ser uno de estos elementos ya que, como estudió Schmit *et al.* (2017), dichas actividades tienen un efecto de incremento del flujo del capital intelectual.

Otro indicador relevante es el de los beneficios que los productores generan al vincularse y colaborar entre ellos. En esta investigación se observa que la vinculación les ha permitido compartir cartera de clientes, darse recomendaciones de producción e intercambiar producto, y en menor medida apoyarse a superar complicaciones cotidianas y darse recomendaciones para la comercialización. Ya en la literatura se ha reportado que los mercados de productores pueden ser una estrategia de incremento del capital social vinculado a la producción de alimentos (VOLPENTESTA; AMMIRATO; DELLA GALA, 2013). Sin embargo, pareciera que las políticas públicas de fomento no consideran este elemento, muy probablemente por su dificultad de evaluación. Dicho de otra forma, limitar la evaluación de los mercados de productores a aspectos económicos es una visión corta desde el abanico de beneficios.

Es importante seguir debatiendo si la vinculación directa del productor con el consumidor proporciona un incremento de la proximidad social. Durante esta investigación se percibe que, a pesar de la proximidad física, la proximidad social en este mercado fue baja. Esto nos lleva a visualizar que los mercados de productores pueden tener dos configuraciones diferentes. Las primeras es en las que existe una elevada proximidad social, muy probablemente derivadas de la gestión ciudadana en las cuales hay comunicación directa entre productores y consumidores así como una distribución de los riesgos como las que menciona Stagl (2002) denominada agricultura apoyada por la comunidad (CSA). En segundo lugar, se tienen iniciativas en las que no existe un fuerte vínculo entre el productor y el consumidor. Como lo demostraron Chen y Scott (2014) para el arraigo del consumidor, la proximidad social puede ser un elemento esencial del éxito de un mercado de productores, tanto en su crecimiento como en su permanencia, y es algo que los promotores de estas iniciativas y los diseñadores de política pública deben considerar. Es decir, pensar que generar un mercado de productores consiste únicamente en la convocatoria de productores y la gestión de espacios, sin considerar la apropiación ciudadana (O'HARA; COLEMAN, 2017), puede llevar a que estas iniciativas no adquieran la fortaleza suficiente, colapsen cuando se acabe el apoyo externo.

Otro aspecto importante es que, a pesar de que los productores observan que su actividad tiene beneficios para el ambiente, el consumidor y para ellos mismos, no cuentan con registros que les permitan evidenciarlos. Esto es particularmente relevante respecto a la promoción de los mercados de productores. Uno de los principales factores clave de los mercados es la ubicación (MORCKEL, 2018), y al menos en México, la disponibilidad de abrir nuevos espacios se ve limitada

ya que la opinión de funcionarios y la normativa no permite que se abran nuevos espacios comerciales y menos en zonas de alto tránsito peatonal, aun cuando se trata de contribuir a la sustentabilidad. Por ello, si se quieren abrir nuevos espacios o mejorar los actuales para los mercados de productores, es importante que los beneficios sean cuantificados y monitoreados, ya que, como menciona Ragona y Mazzocchi (2008), la falta de datos dificulta la estimación de las dinámicas de la regulación y la posibilidad de relaciones endógenas, y por lo tanto se tienen pocos elementos para favorecer la creación de nuevos mercados.

5.2 LIMITACIONES E INVESTIGACIÓN FUTURA

Una de las limitantes de esta investigación, es que el modelo de evaluación se aplicó a un solo mercado de productores. Por ello, es necesario ampliar la aplicación del modelo a más unidades y en estudios longitudinales. Una segunda limitante es que, como se menciona en la literatura, los mercados de productores han tenido diferentes concepciones y variaciones historias de crecimiento en diferentes países, por lo cual es de esperarse que los marcos de evaluación requieran ser adaptados dependiendo las condiciones culturales.

5 CONCLUSIONES

El fomento de mercados agroecológicos de productores es una importante estrategia para impulsar los Objetivos de Desarrollo Sostenible y es necesario generar las herramientas que permitan evidenciar su éxito. Esta investigación cumple el objetivo de diseñar e implementar un modelo de evaluación para mercados de productores desde la perspectiva de los productores. El método fue diseñado para poder ser replicado en otros mercados de productores. La aplicación es rápida ya que es un cuestionario que se aplicaría una vez al año (20 min por participante) y los resultados son de fácil procesamiento, claro que en función de los objetivos de cada país o región se pueden hacer las modificaciones necesarias.

Las métricas de evaluación deben considerar indicadores de proximidad física y social, rentabilidad, beneficios percibidos, áreas de oportunidad, impacto económico, impacto social e impacto ambiental. Asimismo, se pueden incluir métricas de salud en consumidores y productores, así como de la sanidad de los productos. Solo hay que considerar que en función del número de indicadores que se añadan puede aumentar la extensión del instrumento y generar cansancio en los participantes, por lo cual habría que hacer una revisión previa a su aplicación.

Es importante resaltar que los promotores de este tipo de iniciativas deben observar los indicadores de impacto deseados, y en función de ello, establecer mejoras operativas. Esto respaldará la pertinencia de promover los mercados de productores, ya que actualmente, a pesar de la problemática ambiental, se han tenido pocos logros en materia de generación de mercados de productores en México.

AGRADECIMIENTOS

A los participantes y organizadores del Mercado de Productores que colaboraron en la realización de esta investigación.

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Co-production of knowledge among rural women: paths to female recognition in rural areas

Coprodução de conhecimentos entre mulheres rurais: caminhos para o reconhecimento feminino no meio rural

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doi:10.18472/SustDeb.v12n2.2021.37700

Received: 27/04/2021
Accepted: 07/07/2021

ARTICLE – VARIA

ABSTRACT

This article explores the potential of dialogue networks as tools for valuing rural women and overcoming the traditional marginalization of rural women in the countryside. The guiding hypothesis is that when given opportunities to co-produce solutions in a participatory manner and an enabling environment, women can articulate and express their challenges and visualize desirable futures. The results confirm this hypothesis to the extent that women experience and execute these premises in the established spaces of dialogue. The recommendations are for the promotion of actions and policies that provide environments in which women can reframe their role in society and the family.

Keywords: Autonomy. Empowerment. Inclusion. Stakeholders. Productive value.

RESUMO

Este artigo explora o potencial das redes de diálogo como ferramentas de valorização das mulheres rurais e de superação da tradicional marginalização destas no campo. A hipótese norteadora é a de que, quando dadas as oportunidades de coproduzir soluções de maneira participativa e em um ambiente propício, as mulheres conseguem articular e expressar seus desafios e visualizar futuros desejáveis. Os resultados confirmam essa hipótese na medida em que as mulheres vivenciam e executam essas premissas nos espaços de diálogo estabelecidos. As recomendações são para o fomento de ações e políticas que propiciem ambientes em que mulheres possam ressignificar seu papel na sociedade e no núcleo familiar.

Palavras-chave: Autonomia. Empoderamento. Inclusão. Agentes de desenvolvimento. Valor produtivo.

1 INTRODUCTION

The place that women occupy in the productive systems of different rural establishments is commonly less valued than those of men, which is a reality that is accentuated among the social category of family farmers in Brazil (AMORIM; FIÚZA; PINTO, 2015; BUTTO *et al*., 2014; COSTA; BEVILAQUA, 2018; SPANEVELLO *et al*., 2021). This scenario is especially guided by cultural conventions of hierarchy and power relations, thereby positioning women in a type of shadow of the partner. In different global contexts, it is recognized that women's performance in the field is fundamental for the maintenance of productive family systems; however, depending on the sociocultural relations of which they belong, they are little valued or recognized in their decision-making potential, as found, for example, in Uruguay (COURDIN; LITRE; CORREA, 2014; LITRE, 2015), Mexico (CAVALLOTTI VÁZQUEZ *et al*., 2013; LISBOA; LUSA, 2010) and Brazil (HERRERA, 2019; MORAES, 2020; SPANEVELLO; MATTE; BOSCARDIN, 2016; SPANEVELLO *et al*., 2021). In particular, rural women are herein understood as those who have their lives intertwined with the rural environment's productive, reproductive, and sociocultural aspects; they are also identified in the literature as women farmers or rural women (SALES, 2007).

According to the Food and Agriculture Organization of the United Nations (FAO/UN), in general, rural women work more than men, since, in addition to their paid work as producers or family farmers, they are usually in charge of the education, care, and feeding of their children and often of elderly family members or others in a situation of dependence (UN, 2019). On the other hand, despite this image of invisibility in production, the reality, even if not always recognized by the patriarchal system, is that women play a central role in the development of family nuclei, productive activities, and rural communities since they act in these spaces and play roles in the aggregation and organization of rural activities (SILVA *et al*., 2015; SPANEVELLO *et al*., 2021).

Therefore, actions that encompass the gender issue, especially in the rural context, and in activities directly related to food production, figure as a contribution to achieving the Sustainable Development Goals (SDGs), especially the fifth, i.e., "Achieve gender equality and empower all women and girls". Thus, the challenge of a successful workshop[1] strategy with this public makes it possible to provide conditions to these women and to their family and community surroundings to realize the importance of their participation in the decisions and actions of the family group. By expressing their experiences

and having their voices heard, these women allow the empowerment process to develop from their reflections: from how they perceive and understand the world they are a part of and how they understand their importance and value in the rural sphere.

Currently, at least a part of this female population is already being instructed to invest in their education and assume new positions and functions within the family production (FAGUNDES; SPANEVELLO; MATTE, 2021; HORA; NOBRE; BUTTO, 2021). Although these occasional trends seem encouraging, we are far from eliminating the scenario of masculinization of the countryside and the social invisibility of women, which is the dominant pattern for many women in rural areas. Thus, two conceptual bases contribute to the analysis of rural women's work in their communities and family nuclei, namely, the distinction between reproductive and productive spaces and the conception of the co-production of knowledge. Rural women' work is commonly treated as having a "reproductive" value which refers to its function of guaranteeing basic conditions for the family to function, such as ensuring that the family eats for its members to continue working, seeing that clothes are sewn, washed and ironed so that the family can be dressed, making sure that the house is clean, preserving health and ensuring that other members of the family can continue producing, among others.

According to Herrera (2017, p. 2), this means that domestic work has its value related to the capitalist mode of production, which implies "being considered unproductive, given that the product resulting from this laborious effort does not constitute exchange value but rather use-value." For example, in a study about women in family agroindustries in Santa Catarina, Boni (2005) points out that when the product resulting from the work commonly performed by women, such as the processing of food (jam, bread, sweets, cheese), is sold, it migrates to the productive field, while the woman, the subject of production, remains in the reproductive field.

Productive work, in turn, comprises spaces in which women act in activities aimed at exchanging the product generated for monetary value, a scenario in which rural women are often seen as "helpers" (HERRERA, 2017; SPECHT, 2019). That is, productive space or value is about paid work, while reproductive space is understood in the social imaginary[2] as "without monetary value." The resignification of this conception is one of the ways to transform the invisibility of rural women into autonomous agents, insofar as it allows recognizing their role in the prevailing social systems and acknowledging the productive value of rural women's work, which is often nonmonetized. According to Specht (2019), this allocation of women to a reproductive space becomes an obstacle to their productive organization and restricts their participation in different markets so that such issues directly influence the processes of building empowerment conditions. In line with this understanding, the concept of co-production represents a path for this process of change.

Initially coined in the 1980s by the Indian researcher Sheila Jasanoff, the concept of co-production is used to address the production of knowledge within the field of social studies of science (PIMENTA, 2020). The researcher understands that science and society mutually constitute each other, which leads to analyses that "encompass the political, cultural, and legal dimensions of science" (PIMENTA, 2020, p. 51). Jasanoff (2007, p. 33) clarifies that "science fixes our attention on the knowable, leading to an overreliance on fact-finding. Even as scientists recognize the limits of their investigations [...]". The author's international research allows her to assert that disciplined methods are needed to accommodate the partiality of scientific knowledge, calling for "universities to teach modes of knowing that are often left aside in the expansion of scientific understanding and technological capacity" (JASANOFF, 2007, p. 33).

Since Jasanoff's (1990, 2007) contributions, the concept of knowledge co-production has been used as a tool to foster the bringing together of research and practice, the sharing of collective experiences, and the valuing of trajectories and knowledge (BARCELLOS, 2020; MOLNÁR *et al*., 2020; POHL *et al*., 2010). For Armitage *et al*. (2011, p. 1001), knowledge co-production consists of a "collaborative process of bringing together a plurality of sources and types of knowledge to address a defined problem and build an integrated understanding." Therefore, a knowledge co-production space comprises the conjunction of local, tacit, and traditional knowledge with science. In such a way, developing knowledge co-production

processes embraces establishing trust networks among those involved to establish more informed decision-making (FILIPE, *et al*., 2017; HARVEY; COCHRANE; VAN EPP, 2019; MOLNÁR *et al*., 2020). In this sense, Lindoso *et al*. (2020) point out that the use of the concept of co-production of knowledge, when oriented to the solution of local problems with a focus on local actors (in our case, rural women), allows positive results by promoting technical and reflective autonomy of the participating actors.

Accordingly, this study combines the concepts of productive recognition and co-production of knowledge to reflect and promote the autonomy of rural women. Therefore, we seek to understand how the processes of co-production of knowledge translate into specific products or results in applied research through extension actions.

For the more equitable participation of rural women and families in general, access to information through dialogue networks, which generates trust and favours the co-creation of solutions, shows itself as a key to encouraging the permanence of this public in rural areas. Employing participant observation, the current research aims to analyze, from the performance of rural women, the process of co-production of knowledge for the productive valorization of this social category.

2 MATERIALS AND METHODS

The present study is the result of participant observation through the development of an extension project that has the co-production of knowledge as its guiding principle since the researchers became involved in the work in a cooperative way based on a collective process of self-reflection. According to Hernández Sampieri *et al*. (2000, p. 419), observation is not mere contemplation; it implies entering deeply into social situations and maintaining an active role, as well as "permanent reflection, paying attention to details, events, events and interactions". For the authors, observation is an important research mechanism to generate hypotheses for future studies. In particular, reflections should occur during the research process for it to be participatory and not only afterwards, as in traditional research.

Based on this understanding, the activities of the extension project took place in the municipality of Santa Helena in western Paraná state, Brazil (Figure 1). The group of actors involved in the activity consisted of one teacher and two students from the Universidade Tecnológica Federal do Paraná (UTFPR) linked to the Agronomy program, two representatives from the Centro de Referência de Assistência Social (Cras) of the municipality, and a group of rural women with a history of being assisted by Cras. The choice of a preexisting group for action is based on the intention of collaborating with processes of autonomy and combatting the vulnerable situations in which these women find themselves through learning processes, in addition to justifying the importance of this action, insofar as it is a real problem that local society has demanded be addressed with specific actions

Figure 1 | Location of the municipality of Santa Helena in western Paraná
Source: Authors.

The learning process can occur individually or in groups. According to Armitage *et al*. (2011), a focus only on the individual neglects the social and institutional context in which learning occurs. According to Pohl *et al*. (2010), there are two forms of knowledge co-production: the mediated and the now. The first occurs through mediation to facilitate dialogue and shared understandings between academic and non-academic actors. The second, which is of interest to us and guiding our research, comprises collaborative efforts to confront "each other's worldviews in a purposefully open social and intellectual space" (POHL *et al*., 2010, p. 276). In particular, in this second process, participants are deliberately "called upon to deal with the social and cognitive challenges of accommodating contrasting worldviews" (HARVEY; COCHRANE; VAN EPP, 2019, p. 112).

Two workshops were conducted with the rural women's group, which comprised six women, one man (a husband of one of the members), and one child (a granddaughter of one of the members). For the workshops, the other members of the families were invited, which explains the presence of the man and child. The age range of the adult participants was 42 to 68 years old. The purpose was to trigger reflections by the women about their realities through the exchanges, since listening to the stories of others is a way to rethink one's own life. This methodological choice sought to encourage intergender dialogue, which allowed learning during training to be more easily socialized within the family and the community through participatory methods.

In summary, two workshops were held with rural women in a space made available by the municipal school, where a women's group had already been holding meetings for the development of other activities. The first workshop consisted of the initial approach, in which the team introduced itself, explained the purpose of the meetings and invited the women and their families to participate, with their consent and acceptance. On this occasion, the women were consulted about providing authorization to use and disclose the information constructed during the workshops and their consent was documented.

All the women who already participated in activities promoted by Cras were married and had children. Among them, we received information that at least two suffered sexual abuse during their childhood and adolescence, and to some extent, all had previously presented reports and testimonies of psychological violence within the family.

These women identify themselves as housewives, perform productive activities on the properties, often define themselves as "helpers" of their partners, but assume the responsibility for the education and care of the children, the domestic environment of the family with clothes, food, and hygiene, and care for small gardens and the raising of some animals. Their income comes from federal government assistance for those with school-age children and revenue generated by their husbands from the sale of products or services. None of the women market specific products.

The second workshop had three moments. The first featured a poster with the question "What makes you happy?" Everyone present participated in the dialogue while the students recorded the discussion on the poster. For each repetition of a motivating aspect of happiness, an asterisk was incorporated into the poster. During and after the creation of the poster, it was possible to identify similarities within the group, which allowed us to build an amalgam of affinities.

The second moment consisted of the process of identifying the value given to the women's productive work, listing all the activities they carried out and then assigning a monetary value[3] for the women to reflect on the value of the work performed but hidden in the family nuclei by paid work.

The third moment consisted of a World Café exercise, which is a dialogue facilitation technique developed in 1995 by Juanita Brown and David Isaacs. This tool enables groups to access collaborative intelligence, which becomes increasingly powerful as exchanges of places and knowledge take place (BROWN; ISAACS, 2007; FERNANDES, 2015). The four assumptions that guide the World Café, which is presented and established at the beginning of the activities, are as follows: 1) no one is equal to anyone; 2) no one is better than anyone else; 3) no one owns the truth, and 4) everyone has something

to contribute. Facilitation techniques can be a way to engage people in difficult conversations about complex issues. This technique contributed effectively to achieving the desired workshop objectives.

Esquivel Gámez *et al*. (2014) point out that although the technique is particularly recommended for larger groups of people, its application in small groups also leads to good results, generating a pleasant environment and promoting collaborative work. To promote a space for the co-production of knowledge, the participants were divided into two groups. Each was provided with coloured pens and crayons so that they could draw on a poster given to each group, containing the following question: "What was it like to be young, a woman and a man, in the time of your grandparents?" The choice of drawing instead of writing was because some of the participants do not know how to write or can only write their names.

The richness of co-production was found mainly in the process of creating the drawings, a moment when there was dialogue and reflection on what was expressed in answer to the question. The subsequent dialogue allowed for the maturation of ideas, especially by contrasting the present with the desired future.

The students acted as facilitators, encouraging and motivating the participation of all members during the process. Because it was a small group, after the conclusion of the activity, a round of presentations and dialogue about the answers to the guiding question was held.

The main results achieved were drawn from the dialogues conducted during the activities and the presentations of the drawings described and analyzed below. For this analysis, the content analysis technique was used (CRESWELL, 2014). During the production of drawings and presentations, all participants presented their symbologies and the stories behind each image, which allowed them to collectively reflect on the past, present and what they want for the future.

3 RESULTS AND DISCUSSIONS

In the southern Brazilian state of Paraná, the female presence in rural areas has drastically decreased since the 1980s, when more than 1,507,424 women were recorded residing in rural areas, which was then equivalent to 19.76% of the rural population (IBGE, 2011). For the municipality of Santa Helena, on the western coast of the state, 38.14% of the population was female during the same period. The rural exodus, especially by women and young people, led to a drastic reduction in the female presence; in 2010, women accounted for only 6.96% of the state's population and 22.8% of the population of the municipality of Santa Helena (IBGE, 2011). The absence of more up-to-date data and the existence of specific groups to assist women in this region was a particular motivation for carrying out the extension project.

The results achieved thus far can be understood from two aspects: the co-participating team and the public involved. Regarding the executing team, participating in the reading and dialogue spaces before the workshops provided an opportunity for the students who had been working on the project to mature. This is a crucial outcome, with implications in the professional profile of these young students. By sharing experiences and trajectories, their way of seeing the individual has been transformed, thereby enabling them to have a more human understanding of the professional issues that they will find in the labour market. In this regard, Esquivel Gámez *et al*. (2014, p. 414), in applying the World Café technique in study programs in the area of information technology (IT), conclude that the articulation of the two worlds studied – the university and the business world – "is vital for the improvement of the graduate's competencies." Involvement in this exercise will certainly increase the possibilities of creating conditions for the development of the future professional.

Regarding the participating public, the special interest of women in the workshops can be seen by the prompt positive response to participate when the invitation was made, with a special interest in the invitation to participate also being extended to their partners and people with whom they share a home. Despite the low involvement of their partners, the women participated enthusiastically in the activity by sharing their stories and experiences.

In the following workshop, it was possible to understand that this desire for the participation of other family members implied that there was a need for space to speak, even if the speaking is through drawings and not through verbalization. Verbalizing is a work in progress for some of the women participating in the workshop, either because of their fear of the listener reaction or because of the uncertainty regarding the consequences of their speech. In the workshop with the participation of families, it was possible to confront, respectfully and constructively, the contrasts of the answers, particularly between the male/husband participant and the women. It is important to note that the absence of the other partners can at first be understood from the perspective of work, as they cannot abandon the activities performed on the property. However, when we reflect on their absence from the perspective of gender relations, defined conceptually by Scott (1991), it is possible to conclude that women, at least in the community studied, are more likely to reflect on their lives than are men.

The social structure also impacts these men, given that during the workshop, it is necessary to talk about oneself, including sharing memories of childhood and community life. That is, showing feelings or some degree of vulnerability in public does not match the precepts of masculinity expected of rural men (CONNEL, 2018; VIVEROS VIGOYA, 2018). The first activity of the workshop, which consisted of a dialogue on "What makes you happy," enabled the assembled group, students, Cras agents, women, and one man to identify the similarities and shared values (Figure 2). The preponderance of family ties as a mechanism of social recognition and the importance of work for the feeling of inclusion and belonging emerged as the main values pointed out by the participants. In the case of women in particular, beyond economic factors, work characterizes and promotes their identities as rural women and subjects in the productive structure. In this sense, work is a value transmitted from generation to generation. From an early age, with the family understood as the primary responsibility in this process of learning the trades and values that will follow them throughout life, women have learned about animal care, domestic work, agricultural activities, etc. (MORAES, 2020).

Among the shared conceptions, a relevant aspect concerns the image of what these women understand as leisure. In contrast to the answers of the students, the Cras agents, the man, and rural women envision leisure as activities in which they can leave home since the "home" is also a workspace. Therefore, being at home is synonymous with work. The women identified this difference by understanding that those who work outside the home want to stay at home when they have the opportunity, especially as leisure. Therefore, when we return to the issue of the absence of partners of most of the workshop participants, this understanding corroborates the understanding of why there is greater availability of women to participate in activities such as these. Due to commercial activities, men tend to circulate more in the public sphere, whereas there is a tendency for women to be conditioned to the private sphere, which in the rural case would be the family property and the domestic space (SPANEVELLO; MATTE; BOSCARDIN, 2016; SPANEVELLO *et al*., 2021). To this end, encounters such as these make it possible for women to take a break from the daily reality of domestic work and farming.

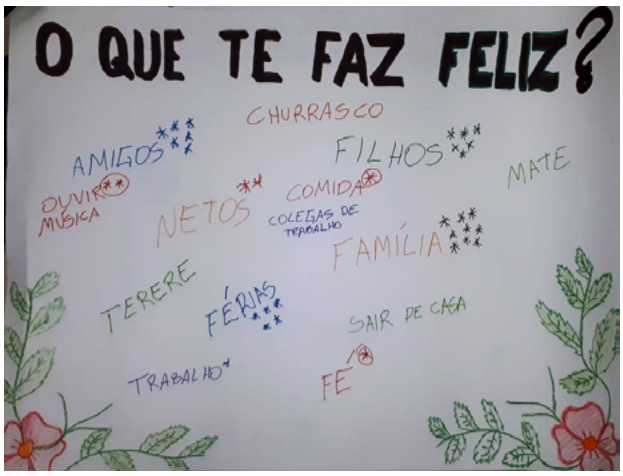

Figure 2 | Dynamics of group connection
Source: Authors' record during the extension activities.

Thus, the dynamics resulted in a change of attitude of the women participants during the workshop itself, in the sense of feeling valued by identifying, on their own, and with the presence of other family members, the value of their work. In a review on the value of productive and reproductive work, Herrera (2017) points out that reversing this situation involves formal and informal institutional arrangements that serve the reproductive spaces occupied by rural women, such as daycare centres, schools, and hospitals. Therefore, by privileging the mercantile production of goods and services, material and immaterial activities "aimed at people's emotional well-being, particularly family domestic work" are made invisible, thus reinforcing the need to reinterpret the understanding of domestic work (MELO; CASTILHO, 2009, p. 154).

In this regard, data from the National Continuous Household Sample Survey, PNADc (IBGE, 2018), point out that 92.2% of women perform household chores. The average number of hours devoted to housework and/or caring for people is 23.8 hours per week for women and 12 hours for men (IBGE, 2018). Continuing with the activities, the results of the third exercise are illustrated in Figure 3.

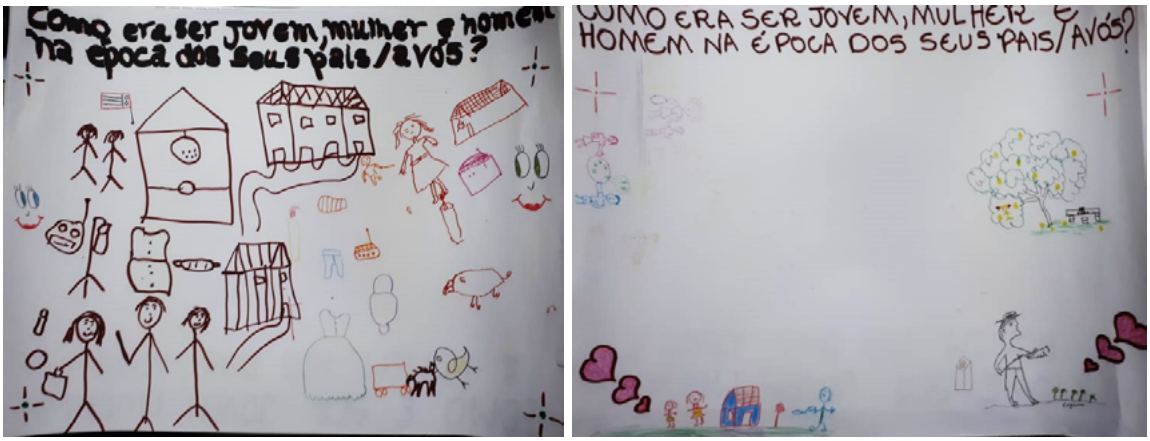

Figure 3 | Results of the deconstruction workshop on "What was it like to be young, female, and male in your parents'/grandparents' time?"
Source: Authors' record during extension activities

In the drawings, the women present images that refer to a childhood close to animals, animal husbandry, and domestic learning (such as making bread and cooking). They also illustrate spaces that were reminiscent of joy, such as the remains of a tree, eating fruit, and playing with animals and plants.

The results for many women show, in general, a childhood that is marked by physical and psychological violence. The effects of these experiences show in their current personality, according to them, in particular through fear and silence. This is confirmed by the drawings that show fathers with instruments of aggression, as in the lower corner of the second image where the image of a doll represents a man with a "soiteira" (an instrument made with a braided bovine leather strap, tied to a piece of wood, used mainly to handle cattle). In the lower corner of the first image, there is an image of three figures representing people, the second of which is a man with a "stick" to punish and "educate", according to the woman who drew the picture.

Regarding violence against women, data presented in the second State Plan for Women's Rights 2018-2021 of Paraná point to a generalized increase in violence against women, in which the homicide rate of women grew between 2001 and 2015 to 26.61 deaths per 100,000 inhabitants (SANTOS; REZENDE; MARTINS, 2018). Additionally, according to the authors, the main type of violence recorded is physical violence, as represented by 39.33% of the records, followed by psychological and moral violence, as with 24.29% of the cases. Therefore, this extension project responds to local demand but also a global one, insofar as the theme of violence emerges as a result of childhood but also allows us to discuss it currently and in the presence of other family members, as well as among the women themselves.

It is important to understand that the women participating in the workshop have been made invisible as the fruit of a society anchored in logic guided by patriarchy; that is, a form of social and family organization in which the man, the patriarch, submits the other members of the family to his power (COLLING; TEDESCHI, 2019) This power system comprises a series of norms that end up negotiating relationships that are imposed on society as a whole and especially within family nuclei (AGUIAR, 2000). The patriarchal logic remains firmly established in Brazilian life and politics: "the position of women, in the family and society in general, since colonization until today, shows that the patriarchal family was one of the matrixes of our current social organization" (NARVAZ; KOLLER, 2006, p. 1).

However, it is fundamental to understand how gender-based power asymmetries are reproduced, which assigns women to situations of vulnerability and hides their value. What the results indicate are trajectories of oppression allied to marriages that reproduce previous family experiences. The existence of this group of women and the actions of Cras (which is a social assistance centre) point to the creation of local measures to combat this devaluation. Even so, the professionals report the challenge of having a small team to meet the needs of such close monitoring, especially because of the frequent reports of violence. The women see the group as a space of shelter and safety. However, it shows the lack of actions aimed at building autonomy through the integration of the family and society itself. This does not cancel out or hide the creation of credit policies, such as Pronaf Mulher (SILVA *et al*., 2015; SPANEVELLO *et al*., 2021), and social assistance policies, such as Bolsa Família, which have been effective at changing this situation in different contexts within Brazil (COUTO, 2020; FRIZZO, 2017; WILLIAMS, 2014). In the case of the women's group, which was the focus of this extension action, Bolsa Família represents the main policy accessed and provides important support for these women.

In line with this, in the drawings, we find symbols associated with domestic work, particularly in that there are few activities that associate childhood with playing. This may be related to the fact that entry into the labour force in rural areas takes place very young and usually occurs between eight and ten years of age (HEREDITA; GARCIA; GARCIA Jr., 1984). Childhood for females is associated with the burden of developing activities related to domestic chores, such as caring for the house and younger siblings, from an early age. In contrast, the look back on childhood for the only male participant consisted of games such as hunting and fishing, which are activities unrelated to housework or memories of violence.

Undoubtedly, the space of co-production of knowledge, through the exchange of experiences during the workshops, allowed those involved to revisit their life stories, which often ended up awakening nostalgic memories of the past. At other times, they were associated with painful, and sometimes traumatic, memories, which, when shared, could be processed and resignified. In this sense, among the women, it was observed that the aspects that emerged from the workshops were related to hard work, the lack of opportunity and space to speak, and the "arranged", often abusive, relationships. For women, their childhood experiences significantly influence how they act today as mothers and grandmothers. For them, attitudes that offer security and freedom of choice so that their daughters/granddaughters can choose their relationships and make their professional decisions are measures to protect them from going through similar situations that have oppressed them.

On the other hand, the male participating in the activity had little sympathy for these elements and considered that the current situation is worrisome since it indicates that men have "lost control" over some aspects of social relationships. For him, social control, even if by oppression, was absent from the current social dynamics. For women, this means freedom of choice and autonomy, whereas, for men, it means loss of power. The interesting thing about the female presence is that, contrary to what one might imagine, the man did not inhibit the women's participation; on the contrary, he showed himself to be more inhibited, while they felt the liberty to speak in their space. Nevertheless, it did not prevent him from expressing his understanding that there was more "control" a few decades ago. This result was important, as the women argued their point of view, especially about the lack of freedom for deciding about assets and professional choice.

In the workshops, gender markers are punctuated in the reflections of those involved so that women tend to resignify a past life marked by work that entailed the absence of autonomy and valorization, while men tend to assimilate the loss of male hegemony. Perceiving these gender relations in the discourse of men and women makes it possible to identify precursor elements of the situation of women in rural contexts, as well as to create alternatives aimed at promoting gender equality, in which both female and male subjects perceive their importance in the social structure, not viewing it as a threat to historically established power relations.

Hooks (2020, p. 30) states that "feminist awareness for men is as essential to the movement", as it is for women's groups, such that without the male presence as an ally in the struggle, the movement tends not to progress. In particular, it is necessary to understand the power relations that guide the internal dynamics of families, as well as of the rural communities in which they are inserted. That is if gender vulnerability is not natural but rather socially and culturally constructed, then resignifying this relationship is a possible path (SALES, 2007; SOARES, 2017). Thus, the results allow us to see that women's autonomy is still recent in Brazilian society and needs to make important advances, especially regarding the participation of other social actors and greater investments of public policies that aim to promote gender equality in rural areas, so as not to reduce these issues to just a women's struggle.

The results allow us to explain that "empowering" women are not necessarily synonymous with fixing women and girls in the countryside. As Freire (1987) said, it is fundamental to generate conditions so that they can choose freely and in an informed way what they want to do to live with dignity (in the countryside or the city). Thus, empowering includes processes that allow women to live the life they desire, without boundaries imposed by gender and patriarchal oppression, as reflected by Sardenberg (2006). This change, although gradual, is taking place, as the data from the Agricultural Census show. In 2006, there were seven establishments run by women who have completed their higher education in the municipality of Santa Helena (IBGE, 2006). In 2017, this number doubled, and there are currently 14 women running agricultural establishments who have completed their higher education (IBGE, 2019). This reality is also found in the scenario of the Brazilian territory, starting with the number of farming establishments run by women, which accounted for 656,255 in 2006 and currently total 946,075, which is an increase of 31% for the period (IBGE, 2006, 2019).

Such results are in line with the analysis and projection that the participants present when analyzing adults' lives in the past, the current reality, and the future projection, especially for children and grandchildren. After all the activities were carried out, at the end of the meeting the women presented a different posture, with shared understandings about the need for their daughters to study and be able to choose their destiny within the available conditions since the rules of the past that guided their future did so with more flexibility than what was experienced by their mothers and grandmothers.

4 CONCLUSIONS

The guiding hypothesis of the participant observation resulting from the research project is that when given the opportunities to co-construct or co-produce solutions in a participatory manner and an enabling environment, historically marginalized women in the countryside can articulate and express their challenges and envision desirable futures, including pathways to achieve that future in a free and informed manner. The results allow us to confirm this hypothesis, as women experience and execute these premises in the established spaces for dialogue.

The use of participatory methodologies to establish a space for the co-production of knowledge has cultivated important seeds that foster reflections in the family nuclei and, especially, in rural women about their protagonism and importance. Breaking with beliefs and sociocultural patterns is challenging, and our challenge is to encourage new ways of looking at female protagonism in the rural context.

Although the central concern throughout this discussion is to explore the potential of dialogue networks as a tool to overcome the marginalized place occupied by women in the rural structure, it is important to clarify that social and gender relations are not static and hierarchical in these rural contexts, since they change according to social and cultural aspects. Notably, the patriarchal structure rooted in the rural environment results in women being subjected to issues such as the invisibility of their labour, the lack of decision-making ability, and low access to education and even marriage. Nevertheless, it would be wrong for the analyses to be limited to the oppressed and oppressors. Therefore, the recommendations are for the promotion of actions and policies that provide spaces for women to resignify, through the co-production of knowledge, their role in society and the family nucleus. Moreover, the need for this dialogue to occur, including with men who, due to the historical structures that guide them, encourage women to remain in situations in which their productive and reproductive value remains invisible.

The extension actions in universities have enabled the recognition of the UTFPR in actions that aim to act on real problems, thereby demonstrating that the professional agronomist who works in participatory extension actions is differentiated in that he has a holistic view of the rural areas by recognizing the importance of sociocultural aspects and productive social categories that are commonly marginalized and made invisible.

ACKNOWLEDGEMENTS

We would like to thank the Social Assistance Reference Center (Cras) of Santa Helena/PR, in particular social workers Andreia Henrichs and Nágila Goeller, and the UTFPR for the scholarship granted. Special thanks to the rural women and their families, who agreed to participate in the workshops and share their stories with us.

This work was supported by INCT/Odisseia-Observatory of socioenvironmental dynamics: sustainability and adaptation to climate, environmental and demographic changes under the National Institutes of Science and Technology Program (Call INCT – MCTI/CNPq/Capes/FAPs n.16/2014), with financial support from Coordination for the Improvement of Higher Education Personnel (Capes): Grant 23038.000776/2017-54; National Council for Scientific and Technological Development (CNPq): Grant 465483/2014-3; Research Support Foundation of the Federal District (FAP-DF): Grant 193.001.264/2017.

NOTES

[1] In particular, the idea of carrying out the extension project that culminated in the participant observation of this research is the result of local need, given the existence of groups of rural women being assisted by organizations prepared for psychosocial support, combined with the interest of students and teachers involved in the action.

[2] Cornelius Castoriadis coined the concept of social imaginary, commonly used to express social representations rooted in the institutions that guide societies. For more information, see Rodrigues (1998).

[3] The activity involved calculating the financial value of rural women's work through a survey of all the activities performed by them, among which were listed: preparing meals, cleaning the house, washing and ironing clothes, taking care of children/grandchildren, taking care of the garden and small animals, etc. After listing all the activities they perform, an estimated value was assigned that would be paid to a person who would perform the corresponding activity using as a hypothesis the absence of the woman, arriving at an estimate of the monetary value of domestic work, commonly invisible in family nuclei.

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Coprodução de conhecimentos entre mulheres rurais: caminhos para o reconhecimento feminino no meio rural

Co-production of knowledge among rural women: paths to female recognition in rural areas

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doi:10.18472/SustDeb.v12n2.2021.37700

Received: 27/04/2021
Accepted: 07/07/2021

ARTICLE – VARIA

RESUMO

Este artigo explora o potencial das redes de diálogo como ferramentas de valorização das mulheres rurais e de superação da tradicional marginalização destas no campo. A hipótese norteadora é a de que, quando dadas as oportunidades de coproduzir soluções de maneira participativa e em um ambiente propício, as mulheres conseguem articular e expressar seus desafios e visualizar futuros desejáveis. Os resultados confirmam essa hipótese na medida em que as mulheres vivenciam e executam essas premissas nos espaços de diálogo estabelecidos. As recomendações são para o fomento de ações e políticas que propiciem ambientes em que mulheres possam ressignificar seu papel na sociedade e no núcleo familiar.

Palavras-chave: Autonomia. Empoderamento. Inclusão. Agentes de desenvolvimento. Valor produtivo.

ABSTRACT

This article explores the potential of dialog networks as tools for valuing rural women and overcoming the traditional marginalization of rural women in the countryside. The guiding hypothesis is that when given opportunities to coproduce solutions in a participatory manner and in an enabling environment, women are able to articulate and express their challenges and visualize desirable futures. The results confirm this hypothesis to the extent that women experience and execute these premises in the established spaces of dialog. The recommendations are for the promotion of actions and policies that provide environments in which women can reframe their role in society and in the family.

Keywords: Autonomy. Empowerment. Inclusion. Stakeholders. Productive value.

1 INTRODUÇÃO

O lugar que mulheres ocupam nos sistemas produtivos de diferentes estabelecimentos rurais é comumente menos valorizado que o dos homens, realidade acentuada entre a categoria social de agricultores familiares no Brasil (AMORIM; FIÚZA; PINTO, 2015; BUTTO *et al*., 2014; COSTA; BEVILAQUA, 2018; SPANEVELLO *et al*., 2021). Esse cenário é orientado, especialmente, por convenções culturais de hierarquia e de relações de poder, posicionando-as em uma espécie de sombra do companheiro. Em diferentes contextos mundiais se reconhece que a atuação das mulheres no campo é fundamental para a manutenção dos sistemas familiares produtivos, mas, dependendo das relações socioculturais às quais pertencem, elas são pouco valorizadas e reconhecidas em seu potencial de tomada de decisão, como encontrado no Uruguai (COURDIN; LITRE; CORREA, 2014; LITRE, 2015), no México (CAVALLOTTI VÁZQUEZ *et al*., 2013; LISBOA; LUSA, 2010) e no Brasil (HERRERA, 2019; MORAES, 2020; SPANEVELLO; MATTE; BOSCARDIN, 2016; SPANEVELLO *et al*., 2021), por exemplo. Particularmente, mulheres rurais são aqui entendidas como aquelas que têm sua vida entrelaçada ao meio rural, nos aspectos produtivos, reprodutivos e socioculturais, também encontrado na literatura como mulheres agricultoras ou mulheres do campo (SALES, 2007).

De acordo com a Organização para a Alimentação e a Agricultura das Nações Unidas (FAO/ONU), de maneira geral, as mulheres rurais trabalham mais que os homens, visto que, além do trabalho pago como produtoras ou agricultoras familiares, elas habitualmente são encarregadas de educação, cuidados e alimentação de seus filhos e, muitas vezes, das pessoas idosas ou em situação de dependência (ONU, 2019). Por outro lado, apesar dessa imagem de invisibilidade na produção, a realidade, mesmo que nem sempre reconhecida pelo sistema patriarcal, é que as mulheres têm protagonismo central no desenvolvimento nos núcleos familiares, nas atividades produtivas e nas comunidades rurais, uma vez que atuam nesses espaços desempenhando papéis de agregação e organização das atividades rurais (SILVA *et al*., 2015; SPANEVELLO *et al*., 2021).

Por isso, ações que englobem a temática de gênero, especialmente no contexto rural e em atividades diretamente relacionadas à produção de alimentos, figuram como contribuição para alcançar os

desafios dos Objetivos de Desenvolvimento Sustentável (ODS), especialmente o quinto deles, "Alcançar a igualdade de gênero e empoderar todas as mulheres e meninas". Assim, o desafio de uma estratégia de oficinas[1] bem-sucedida com esse público possibilita fornecer condições para que essas mulheres, e para que o seu entorno familiar e comunitário, percebam a importância de sua participação nas decisões e nas ações do grupo familiar. Com isso, o fato de essas mulheres poderem expressar suas experiências, de modo a terem suas vozes ouvidas, permite também que o processo de empoderamento ocorra a partir de suas próprias reflexões, isto é, a partir de como se percebem e entendem o mundo que integram, compreendendo sua importância, e consequente valorização na esfera rural.

Atualmente, de certa forma, ao menos uma parcela dessa população feminina já está sendo educada para investir em sua formação e assumir novos cargos e funções dentro da produção familiar (FAGUNDES; SPANEVELLO; MATTE, 2021; HORA; NOBRE; BUTTO, 2021). Apesar de essas tendências pontuais parecerem encorajadoras, estamos longe de descartar o cenário de masculinização do campo e de invisibilidade social que é o padrão dominante para muitas mulheres no meio rural. Assim, duas bases conceituais contribuem para a análise da atuação das mulheres rurais em suas comunidades e núcleos familiares, que compreendem a distinção entre espaço reprodutivo e produtivo, e a concepção de coprodução de conhecimentos. Comumente se trata o trabalho das mulheres rurais como tendo valor "reprodutivo", que se refere à sua função de garantir as condições básicas para que a família possa ter sua funcionalidade, como, por exemplo, garantir que a família coma para que continue trabalhando; garantir que a roupa esteja costurada, lavada e passada para que a família continue se vestindo; garantir que a casa esteja limpa para preservar a saúde e que os demais membros da família continuem produzindo, etc.

Segundo Herrera (2017, p. 2), isso significa que o trabalho doméstico tem seu valor relacionado ao modo de produção capitalista, o que implica "ser considerado improdutivo, tendo em vista que o produto resultante desse esforço laborioso não se constitui em valor de troca e sim valor de uso". A exemplo, em estudo sobre mulheres nas agroindústrias familiares de Santa Catarina, Boni (2005) aponta que no momento em que o produto resultante do trabalho comumente exercido por mulheres – como o processamento de alimentos (geleias, pães, doces, queijo) – passa a ser comercializado, esse migra para o campo produtivo, enquanto a mulher, sujeito da produção, permanece no reprodutivo.

O trabalho produtivo, por sua vez, compreende espaços em que mulheres atuam em atividades destinadas à troca do produto gerado por um valor monetário, cenário em que as mulheres rurais são frequentemente vistas como "ajudantes" (HERRERA, 2017; SPECHT, 2019), ou seja, o espaço ou valor produtivo trata-se de trabalho remunerado, enquanto o espaço reprodutivo é entendido no imaginário social[2] como "sem valor monetário". A ressignificação dessa concepção é um dos caminhos para transformar a invisibilidade das mulheres rurais em autonomia, na medida em que permite reconhecer seu papel nos sistemas sociais vigentes e o valor produtivo do trabalho feminino rural, com frequência não monetizado.

Conforme Specht (2019), essa alocação das mulheres a um espaço reprodutivo torna-se obstáculo à organização produtiva delas e restringe sua participação nos diferentes mercados, de modo que tais questões influenciam diretamente os processos de construção das condições de empoderamento. Aliado a esse entendimento, o conceito de coprodução representa um caminho para esse processo de mudança.

Cunhado inicialmente na década de 1980, pela pesquisadora indiana Sheila Jasanoff, o conceito de coprodução foi utilizado para tratar da produção de conhecimento dentro do campo dos Estudos Sociais da Ciência (PIMENTA, 2020). A pesquisadora entende que Ciência e sociedade se constituem reciprocamente, o que conduziu à realização de análises que "abarcam as dimensões políticas, culturais e legais da Ciência" (PIMENTA, 2020, p. 51). Jasanoff (2007, p. 33) esclarece que "a ciência fixa nossa atenção no conhecível, levando a uma dependência excessiva da descoberta de fatos. Mesmo quando os cientistas reconhecem os limites de suas próprias investigações [...]". As pesquisas internacionais da autora permitem-na afirmar que é necessária a criação de métodos disciplinados para acomodar a parcialidade do conhecimento científico, clamando para que as "universidades ensinem modos de

conhecimento que muitas vezes são deixados de lado na expansão da compreensão científica e da capacidade tecnológica" (JASANOFF, 2007, p. 33).

Desde as contribuições de Jasanoff (1990, 2007), o conceito de coprodução de conhecimento tem sido utilizado como instrumento para fomentar a aproximação entre pesquisa e prática, o compartilhamento de experiências coletivas, e a valorização das trajetórias e conhecimentos (BARCELLOS, 2020; MOLNÁR *et al*., 2020; POHL *et al*., 2010). Para Armitage *et al*. (2011, p. 1001), coprodução de conhecimento consiste em um "processo colaborativo de reunir uma pluralidade de fontes e tipos de conhecimento para abordar um problema definido e construir uma compreensão integrada". Portanto, um espaço de coprodução de conhecimento compreende a conjunção entre conhecimento local, tácito e tradicional, com ciência. De tal modo, desenvolver processos de coprodução de conhecimento abarca estabelecer rede de confiança entre os envolvidos para estabelecer tomada de decisão mais informada (FILIPE, *et al*., 2017; HARVEY; COCHRANE; VAN EPP, 2019, MOLNÁR *et al*., 2020). Nesse sentido, Lindoso *et al*. (2020) apontam que o uso do conceito de coprodução de conhecimento, quando orientado à solução de problemas locais, com enfoque em atores locais (em nosso caso, as mulheres rurais), permite resultados positivos ao promover a autonomia técnica e reflexiva dos atores participantes.

Diante disso, este estudo alia os conceitos de reconhecimento produtivo e coprodução de conhecimento para refletir e promover autonomia das mulheres rurais. Portanto, buscamos compreender como os processos de coprodução de conhecimento se traduzem em produtos ou resultados específicos em pesquisas aplicadas por meio de ações de extensão.

Por isso, para uma participação mais equitativa das mulheres rurais, assim como para as famílias em geral, o acesso à informação por meio de redes de diálogo, que gerem confiança e favoreçam a cocriação de soluções, mostra-se como uma chave para incentivar a permanência desse público no meio rural. Assim, por meio da observação participante, a pesquisa tece como propósito analisar, a partir da atuação junto a mulheres rurais, o processo de coprodução de conhecimento para a valorização produtiva dessa categoria social.

2 MATERIAIS E MÉTODOS

O presente estudo trata do resultado da observação participante por meio do desenvolvimento de um projeto de extensão que tem como princípio norteador a coprodução de conhecimento, uma vez que os pesquisadores se envolveram no trabalho de forma cooperativa, baseados em processos de autorreflexão coletiva. Conforme Hernández Sampieri *et al*. (2000, p. 419), a observação não é uma mera contemplação, implica entrar profundamente em situações sociais e manter um papel ativo, assim como "uma reflexão permanente, atento aos detalhes, acontecimentos, eventos e interações". Para os autores, a observação configura importante mecanismo de pesquisa para gerar hipóteses para futuros estudos. Em particular, as reflexões devem ocorrer durante o processo de pesquisa, não apenas e somente depois, como em uma pesquisa tradicional, por isso ela deve ser participativa.

Partindo desse entendimento, as atividades do projeto de extensão ocorreram no município de Santa Helena, no oeste do estado do Paraná, Brasil (Figura 1). O grupo de atores envolvidos na atividade foi constituído por uma docente e duas discentes da Universidade Tecnológica Federal do Paraná (UTFPR) vinculadas ao curso de Agronomia, duas agentes do Centro de Referência de Assistência Social (Cras) do município, e por um grupo de mulheres rurais com histórico de atendimento pelo Cras. A escolha de um grupo preexistente para atuação parte do intuito de colaborar com processos de autonomia e combate às situações de vulnerabilidade em que essas mulheres se encontram por meio de processos de aprendizado, além de justificar a importância dessa ação na medida em que se trata de um problema real e que a sociedade local tem demandado ações pontuais.

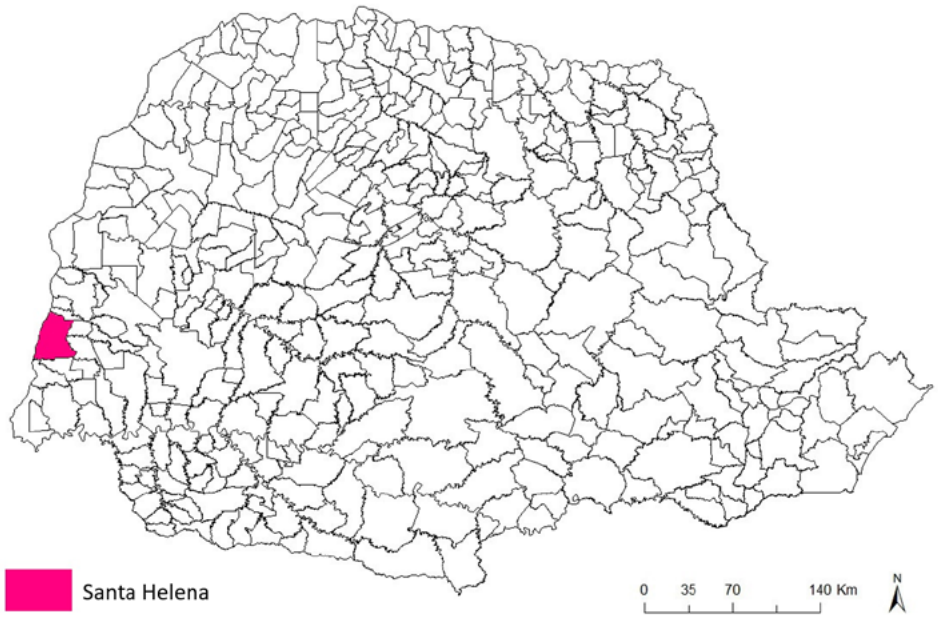

Figura 1 | Localização do município de Santa Helena, no oeste do Paraná
Fonte: Elaboração própria.

O processo de aprendizado pode ocorrer de forma individual ou em grupo. Segundo Armitage *et al*. (2011), um foco apenas no indivíduo negligencia o contexto social e institucional em que ocorre a aprendizagem. Segundo Pohl *et al.* (2010), há duas formas de coprodução de conhecimento: mediada e *agora*. A primeira ocorre por meio de uma mediação para facilitar o diálogo e entendimentos compartilhados entre atores acadêmicos e não acadêmicos. A segunda, de nosso interesse e norteadora de nossa pesquisa, compreende esforço colaborativo, de modo a confrontar "visões de mundo umas das outras em um espaço social e intelectual propositalmente aberto" (POHL *et al*., 2010, p. 276). Em particular, nesse segundo processo, os participantes são deliberadamente "chamados a lidar com os desafios sociais e cognitivos de acomodar visões de mundo contrastantes" (HARVEY; COCHRANE; VAN EPP, 2019, p. 112).

Assim, foram realizadas duas oficinas com o grupo de mulheres rurais, compreendendo seis mulheres, um homem (marido de uma das integrantes) e uma criança (neta de uma das integrantes). Para as oficinas, foram convidados os demais integrantes das famílias, o que explica a presença de um homem e de uma criança. A faixa etária dos participantes adultos era de 42 a 68 anos. O propósito era de que as trocas se tornassem gatilhos de reflexão sobre a sua realidade, visto que ouvir a história do outro é um meio para repensar a própria. Essa escolha metodológica buscou incentivar o diálogo intergênero, permitindo que o aprendizado durante o treinamento fosse mais facilmente socializado no interior da família e da comunidade por meio de métodos participativos.

De forma resumida, houve duas oficinas com as mulheres rurais, realizadas em espaço disponibilizado pela escola municipal, no qual o grupo de mulheres já vinha realizando encontros para o desenvolvimento de outras atividades. A primeira oficina consistiu na aproximação inicial, em que a equipe se apresentou e expôs a proposta para os encontros, convidando as mulheres e suas famílias a participarem, tendo o consentimento e aceite. Nessa oportunidade, as mulheres foram consultadas sobre a autorização para utilização e divulgação das informações construídas durante as oficinas, documentando a autorização para isso.

Todas as mulheres, as quais já participavam de atividades promovidas pelo Cras, são casadas e têm filhos. Dentre elas, tem-se a informação de que pelo menos duas sofreram abusos sexuais na infância e na adolescência, e, em alguma medida, todas já apresentaram relatos e depoimentos de violência psicológica no âmbito familiar.

Essas mulheres se identificam como donas de casa, realizam atividades produtivas nas propriedades, muitas vezes se autodefinindo como "ajudantes" dos companheiros, mas assumindo a responsabilidade de educação e do cuidado com os filhos, no contexto doméstico com roupas, comida e higiene do ambiente familiar, além do cuidado com pequenas hortas e criação de alguns animais. A renda que cabe a elas advém de assistência do governo federal para aquelas com filhos em idade escolar, e da dependência da renda gerada pelo marido na venda de produtos ou de serviço. Nenhuma das mulheres comercializa produtos em específico.

A segunda oficina teve três momentos. O primeiro contou com um cartaz contendo a pergunta: "O que te faz feliz?". Todos os presentes participaram do diálogo, enquanto as estudantes faziam o registro no cartaz. A cada repetição de aspecto motivador de felicidade, um asterisco era incorporado no cartaz. Durante e ao fim da confecção do cartaz, foi possível encontrar semelhanças no grupo, o que permitiu construir um amálgama de afinidades.

O segundo momento consistiu em um processo de identificação de valorização do trabalho produtivo das mulheres, elencando todas as atividades realizadas por elas e, posteriormente, estabelecendo um valor monetário[3] para tais, a fim de refletir sobre o valor do trabalho realizado e ocultado nos núcleos familiares pelos trabalhos remunerados.

O terceiro momento compreendeu a aplicação da técnica Café Mundial (*World Café*), que consiste em uma técnica de facilitação de diálogo desenvolvida em 1995, por Juanita Brown e David Isaacs. Essa ferramenta capacita grupos a terem acesso a uma inteligência colaborativa, que se torna cada vez mais potente na medida em que as trocas de lugares e de conhecimentos acontecem (BROWN; ISAACS, 2007; FERNANDES, 2015). Os quatro pressupostos que norteiam o Café Mundial, apresentados e estabelecidos desde o início das atividades são: 1) Ninguém é igual a ninguém; 2) Ninguém é melhor do que ninguém; 3) Ninguém é dono da verdade; e 4) Todos têm com o que contribuir. Técnicas de facilitação podem ser um caminho para engajar pessoas em conversas difíceis sobre assuntos complexos. Essa técnica contribuiu de maneira efetiva para alcançar os objetivos desejados com a oficina.

Esquivel Gámez *et al*. (2014) apontam que, apesar de a técnica ser recomendada especialmente para grupos maiores de pessoas, sua aplicação em pequenos grupos apresentou bons resultados, gerando ambiente agradável e trabalhos colaborativos. Para a promoção de espaço de coprodução de conhecimento, os participantes foram divididos em dois grupos, ambos munidos com canetas coloridas e giz de cera, para que desenhassem sobre um cartaz entregue a cada grupo, contendo a seguinte pergunta: "Como era ser jovem, mulher e homem na época dos seus avós?". A escolha de desenho em vez da escrita se deve ao fato de que algumas das participantes não sabem escrever, ou apenas o fazem para o próprio nome.

A riqueza da coprodução está principalmente no processo de elaboração dos desenhos, momento em que havia diálogos e reflexões sobre o que seria expresso para representar resposta àquela pergunta. O diálogo posterior permitiu amadurecimento, especialmente pelo contraste com a atualidade e com o futuro almejado.

As estudantes atuaram como facilitadoras, incentivando e motivando a participação de todos durante o processo. Em razão de tratar-se de pequeno grupo, após a conclusão da atividade, foi realizada roda de apresentação e de diálogo sobre as respostas à pergunta orientadora.

Os principais resultados alcançados foram identificados a partir dos diálogos construídos durante as atividades e as apresentações dos desenhos, os quais estão descritos e analisados na sequência. Para essa análise, foi utilizada a técnica de análise de conteúdo (CRESWELL, 2014), uma vez que, durante a produção dos desenhos e das apresentações, todos os participantes apresentaram suas simbologias e histórias por trás de cada imagem, permitindo que refletissem coletivamente sobre o passado, o presente e o que almejam para o futuro.

3 RESULTADOS E DISCUSSÕES

Particularmente, no estado do Paraná, no sul do Brasil, a presença feminina no meio rural reduziu drasticamente desde a década de 1980, quando foram registradas mais de 1.507.424 mulheres residindo no meio rural, o equivalente a 19,76% da população rural (IBGE, 2011). Ao observar essa mesma relação para o município de Santa Helena, na costa oeste do estado, o montante significava 38,14% para o mesmo período. No entanto, o êxodo rural, protagonizado especialmente por mulheres e jovens, conduziu a um contexto em que a presença feminina representava, em 2010, 6,96% no estado e 22,8% no município de Santa Helena, evidenciando marcante redução (IBGE, 2011). Em particular, nesse cenário, a ausência de dados mais atualizados e a existência de grupos específicos para atendimento de mulheres motivaram a realização do projeto de extensão.

Os resultados alcançados até o momento podem ser entendidos sobre dois aspectos: da equipe coparticipante e do público envolvido. A respeito da equipe executora, pode-se destacar que a oportunidade dos espaços de leitura e diálogo prévio às oficinas oportunizaram especial amadurecimento das estudantes que vêm atuando no projeto. Esse resultado torna-se essencial ser tratado, na medida em que isso implica o perfil profissional dessas jovens estudantes, que, por meio do compartilhamento de experiências e trajetórias, transformaram seu modo de ver o indivíduo, capacitando-as com um olhar mais humano perante questões profissionais que virão a encontrar no mercado de trabalho. A esse respeito Esquivel Gámez *et al*. (2014, p. 414) – ao aplicarem a técnica do Café Mundial em programas de estudos na área de Tecnologia de Informação (TI) –, concluem que a aproximação dos dois mundos estudados, a universidade e o mundo dos negócios, "é vital para o aprimoramento das competências do graduado", de modo que certamente aumentará as possibilidades de criar condições para o desenvolvimento do futuro profissional.

A respeito do público atendido, o especial interesse das mulheres nas oficinas pode ser constatado pela pronta resposta positiva quando o convite foi realizado, principalmente pelo aspecto de o convite ser extensivo aos companheiros e pessoas com quem dividem a casa para que participassem da atividade. Apesar da baixa adesão dos companheiros, as mulheres participaram com entusiasmo da atividade, compartilhando suas histórias e experiências.

Na oficina seguinte, foi possível compreender que esse anseio pela participação dos demais integrantes da família significava a necessidade de espaço de fala, mesmo que a maneira da fala seja por meio de desenhos, e não propriamente pela verbalização. Isso porque verbalizar é um passo que está em construção para algumas das mulheres participantes da oficina, seja por medo da reação do ouvinte, ou pela incerteza das consequências de sua fala. Na oficina com a participação das famílias, foi possível confrontar, de forma respeitosa e construtiva, os contrastes das respostas entre o homem/marido participante e as mulheres especialmente. É importante observar que a ausência dos demais companheiros, em um primeiro momento, pode ser compreendida a partir da perspectiva do trabalho, de modo que estes não podiam abandonar as atividades executadas na propriedade. Porém, quando refletimos a partir da ótica das relações de gênero – definida conceitualmente por Scott (1991) –, é possível analisar que as mulheres, pelo menos nessa comunidade estudada, estão mais propensas a refletir sobre suas vidas do que os homens.

Tendo em vista que durante a oficina seria necessário falar sobre si, retomar memórias da infância e da vida em comunidade, a estrutura social também acaba impactando esses homens, isto é, demonstrar sentimentos, ou até mesmo algum tipo de fragilidade em público, não condiz com os preceitos de masculinidade esperados do homem rural (CONNEL, 2018; VIVEROS VIGOYA, 2018). A primeira atividade da oficina, que consistiu em diálogo sobre "O que faz você feliz", possibilitou que o grupo reunido, estudantes, agentes do Cras, mulheres e um homem, vislumbrassem as semelhanças e valores em comum (Figura 2).

A preponderância dos laços familiares como mecanismo de reconhecimento social e a importância do trabalho, para o sentimento de inclusão e pertencimento, surgiram como principais valores apontados

pelos participantes na dinâmica. Pensando especificamente sobre o relato das mulheres, para além de fatores econômicos, o trabalho é caracterizador e fomentador de suas identidades como mulheres rurais, como sujeitos na estrutura produtiva. Nesse sentido, o trabalho é um valor transmitido de geração para geração, desde tenra idade, sendo a família compreendida como responsável principal nesse processo de aprendizagem dos ofícios e valores que se seguirão por toda a vida, nos quais desde a infância se aprende sobre o cuidado com os animais, trabalho doméstico, atividades agrícolas, etc. (MORAES, 2020).

Entre as concepções compartilhadas, um aspecto relevante diz respeito à imagem do que essas mulheres compreendem como lazer. Em contraste às respostas das estudantes, das agentes do Cras e do homem, as mulheres rurais vislumbram o lazer como atividades em que possam sair de casa, uma vez que o "lar" é também espaço de trabalho. Portanto, estar em casa é sinônimo de trabalho. As mulheres identificaram essa diferença ao compreenderem que quem trabalha fora de casa quer ficar no seu lar, quando tem oportunidade, em especial como lazer. Diante disso, ao retomar a questão da ausência dos companheiros da maioria das participantes da oficina, tal compreensão corrobora o entendimento do porquê há uma maior disponibilidade feminina para participar de atividades como essas. Enquanto os homens, em decorrência das atividades comerciais, tendem a circular mais na esfera pública, há uma propensão das mulheres estarem condicionadas à esfera privada, que, no caso rural, seria a propriedade familiar e o espaço doméstico (SPANEVELLO; MATTE; BOSCARDIN, 2016; SPANEVELLO *et al*., 2021). Para tanto, encontros como esses possibilitam que elas saiam da realidade cotidiana de trabalho doméstico e da lavoura.

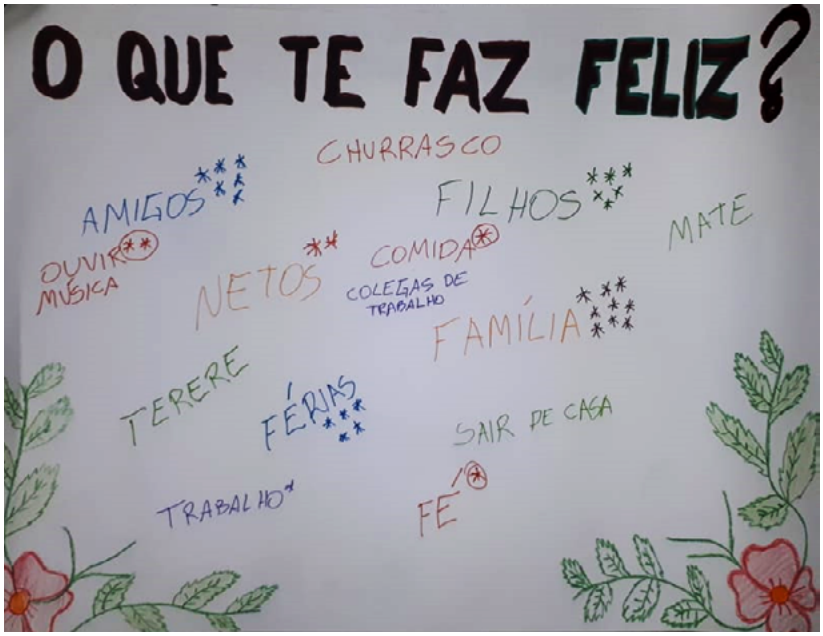

Figura 2 | Dinâmica de conexão do grupo
Fonte: Registro dos autores durante as atividades de extensão.

Assim, a dinâmica resultou em mudança de postura das mulheres participantes durante a própria oficina, no sentido de sentirem-se valorizadas ao identificarem, por conta própria, e com a presença de outras pessoas da família, o valor do seu trabalho. Em revisão sobre o valor do trabalho produtivo e reprodutivo, Herrera (2017) aponta que reverter essa situação perpassa por arranjos institucionais formais e informais que atendam a espaços reprodutivos ocupados pelas mulheres rurais, como creches, escolas, hospitais, entre outros. Portanto, ao privilegiar a produção mercantil de bens e serviços, ficam invisibilizadas as atividades materiais e imateriais "dirigidas ao bem-estar emocional das pessoas, particularmente o trabalho familiar doméstico", reforçando a necessidade de reinterpretar o entendimento de trabalho doméstico (MELO; CASTILHO, 2009, p. 154).

A esse respeito, os dados da Pesquisa Nacional por Amostra de Domicílios Contínua – PNADc (IBGE, 2018) apontam que a taxa de realização de afazeres domésticos é de 92,2% para mulheres. A média de horas dedicadas aos afazeres domésticos e/ou aos cuidados de pessoas foi de 23,8 horas por semana para mulheres e 12 horas para homens (IBGE, 2018). Na continuidade das atividades, os resultados da terceira dinâmica estão ilustrados na Figura 3.

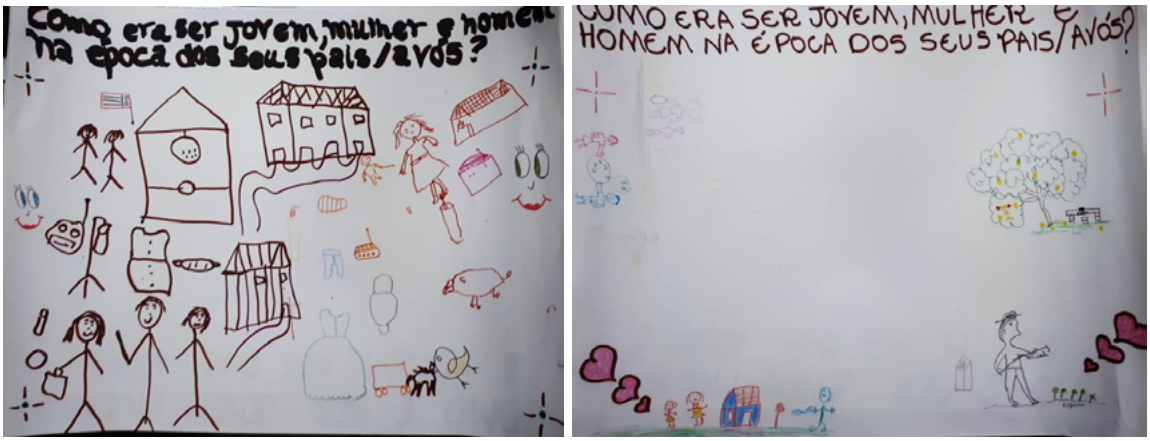

Figura 3 | Resultado da oficina de desconstrução sobre "Como era ser jovem, mulher e homem na época dos seus pais/avós?"
Fonte: Registro dos autores durante as atividades de extensão

Entre os desenhos, as mulheres apresentam imagens que remetem a uma infância próxima de animais, da criação animal e de aprendizados domésticos (como fazer pão e cozinhar). Também ilustram os espaços que remetiam à alegria, como a sombra de uma árvore, comer frutas e brincar com animais e com plantas.

Os resultados mostram, de maneira geral, uma infância, para muitas mulheres, marcada por violência física e psicológica, com resquícios na personalidade atual, segundo elas mesmas, especialmente representados pelo medo e pelo silêncio. Isso é confirmado pelas expressões nos desenhos, que mostram pais com instrumentos de agressão, como no canto inferior da segunda imagem, um boneco representando um homem com uma "soiteira" (instrumento feito com uma tira de couro bovino trançada, amarrada a um pedaço de madeira, utilizada mormente para manejar bovinos). No canto inferior da primeira imagem, há três figuras representando pessoas, a segunda delas é um homem com uma "vara" para castigar e "educar", segundo a mulher que realizou o desenho.

No que concerne à violência contra a mulher, dados apresentados no segundo Plano Estadual dos Direitos da Mulher 2018-2021 do Paraná apontam para um aumento generalizado da violência contra a mulher, em que o número de homicídios de mulheres por agressão cresceu, entre 2001 e 2015, representado na taxa de 26,61 mortes por 100 mil habitantes (SANTOS; REZENDE; MARTINS, 2018). Ainda segundo as autoras, o principal tipo de violência registrado é o físico, representado por 39,33% dos registros, seguido de violência psicológica e moral com 24,29% dos casos. Portanto, esse projeto de extensão atende a uma demanda local, mas também global, na medida em que o tema da violência emerge como resultado da infância, mas também permite debatê-lo na atualidade e na presença de outros integrantes da família, assim como entre as próprias mulheres.

É importante entender que as mulheres participantes da oficina estão invisibilizadas como fruto de uma sociedade ancorada em lógicas orientadas pelo patriarcado, isto é, a uma forma de organização social e familiar na qual o homem, o patriarca, submete os demais membros da família ao seu poder (COLLING; TEDESCHI, 2019). Esse sistema de poder compreende uma série de normativas que acabam por arbitrar as relações, inferindo sobre a sociedade como um todo e especialmente dentro dos núcleos familiares (AGUIAR, 2000). A lógica patriarcal permanece na vida e na política brasileira, de modo que "a posição da mulher, na família e na sociedade em geral, desde a colonização até hoje, demonstra que a família patriarcal foi uma das matrizes de nossa organização social atual" (NARVAZ; KOLLER, 2006, p. 1).

Entretanto, é fundamental entender como se reproduzem as assimetrias de poder baseadas no gênero, que alocam essas mulheres em situações de vulnerabilidade e ocultam seu valor. O que os resultados apontam são trajetórias de opressão, aliadas a casamentos que reproduzem experiências familiares anteriores. A existência desse grupo de mulheres e a atuação do Cras apontam a criação de medidas locais de combate a essa desvalorização. Mesmo assim, as profissionais relatam o desafio de disporem de uma equipe pequena para a necessidade de um acompanhamento tão próximo, especialmente pelos relatos frequentes de violência e do quanto essas mulheres veem no grupo um espaço de acolhimento e de segurança. Porém, evidenciam a inexistência de ações voltadas para a construção de autonomia por meio da integração da família e da própria sociedade. Isso não anula e não oculta a criação de políticas de crédito, como o Pronaf Mulher (SILVA *et al*., 2015; SPANEVELLO *et al*., 2021), e de assistência social, como o Bolsa Família, que foram eficientes para modificar esse cenário em diferentes contextos do território brasileiro (COUTO, 2020; FRIZZO, 2017; WILLIAMS, 2014). No caso do grupo de mulheres foco dessa ação de extensão, o Bolsa Família representa a principal política acessada e com importante apoio a essas mulheres.

Aliado a isso, nos desenhos são encontrados símbolos atrelados ao trabalho doméstico, especialmente com poucas atividades que associem a infância a brincadeiras. Isso pode estar relacionado ao fato de a entrada como força de trabalho no meio rural ser precoce, normalmente ocorrendo entre os oito e dez anos de idade (HEREDITA; GARCIA; GARCIA JR., 1984), associado ao encargo do desenvolvimento de atividades relacionadas às tarefas domésticas, como o cuidado da casa e dos irmãos mais novos, desde tenra idade. Em particular, o olhar sobre a infância para o único homem participante da atividade consistiu em brincadeiras como caça e pesca, sem relação com trabalhos domésticos ou recordações de violência.

Sem dúvida alguma, o espaço de coprodução de conhecimento, por meio da troca de experiências durante as oficinas, permitiu que os envolvidos pudessem retomar suas próprias histórias de vida, o que muitas vezes acabou por despertar memórias saudosas dos tempos passados, enquanto, em outros momentos, foram associados a lembranças dolorosas, e, por vezes, traumáticas, que, ao serem compartilhadas, puderam ser trabalhadas e ressignificadas. Diante disso, entre as mulheres, observa-se que os aspectos que emergiram relacionam-se à penosidade do trabalho à época, à falta de oportunidade e de espaço de fala, e aos relacionamentos “arranjados”, muitas vezes abusivos.

Para as mulheres, suas experiências na infância influenciam significativamente como agem hoje enquanto mães e avós. Para elas, atitudes que ofereçam segurança e liberdade de escolha para que suas filhas/netas possam escolher seus relacionamentos e tomar suas decisões profissionais são medidas para protegê-las de passarem por situações que as oprimiram.

Por outro lado, o homem participante da atividade pouco compactuou com esses elementos, considerando que o cenário atual preocupa, uma vez que indica que “perderam o controle” sobre alguns aspectos das relações sociais, ou seja, para ele havia um controle social, mesmo que pela opressão, ausente na dinâmica social atual. Para as mulheres, isso significa liberdade de escolha e autonomia; para homens, perda de poder. O interessante da presença feminina é que, ao contrário do que se possa imaginar, o homem não inibiu a participação das mulheres, pelo contrário, ele mostrou-se mais inibido, enquanto elas sentiam-se no seu espaço de fala. Mesmo assim, não impediu que ele manifestasse seu entendimento de que havia mais “controle” há algumas décadas. Esse resultado foi importante, pois as mulheres argumentaram o ponto de vista delas, especialmente sobre a falta de liberdade com relação a decidir sobre patrimônio e escolha profissional.

Portanto, nas oficinas, os marcadores de gênero são pontuados nas reflexões dos envolvidos, de modo que as mulheres tendem a ressignificar um passado de vida marcado pelo trabalho, pela ausência de autonomia e de valorização, enquanto os homens tendem a assimilar a perda da hegemonia masculina. Perceber essas relações de gênero no discurso de homens e mulheres possibilita identificar elementos percursores da situação das mulheres em contextos rurais, bem como de criar alternativas que visem

promover uma igualdade de gênero, em que tantos os sujeitos femininos quanto os masculinos percebam sua extrema importância na organização social e não a compreendam como uma ameaça às relações de poder historicamente estabelecidas.

Hooks (2020, p. 30) afirma que "a conscientização feminista para homens é tão essencial para o movimento" quanto para o grupo de mulheres, de tal modo que sem a presença masculina como aliada à luta o movimento tende a não progredir. Em especial, é preciso compreender as relações de poder que orientam as dinâmicas internas das famílias, como também das comunidades rurais em que estão inseridas, ou seja, se a vulnerabilidade de gênero não é natural, mas sim construída social e culturalmente, ressignificar essa relação é um caminho possível (SALES, 2007; SOARES, 2017). Assim, os resultados permitem constatar que a autonomia das mulheres ainda é recente na sociedade brasileira e necessita de importantes avanços, em especial no tocante à participação de outros atores sociais e de maiores investimentos em políticas públicas que visem promover a igualdade de gênero no meio rural, de modo a não reduzir essas questões para apenas uma luta das mulheres.

Os resultados permitem explicar que, na verdade, "empoderar" mulheres não é necessariamente sinônimo de fixar mulheres e as meninas no campo, como dizia Freire (1987), é fundamental gerar condições para que elas possam escolher livremente, e de maneira informada, o que elas querem fazer para viver dignamente (no campo ou na cidade). Assim, empoderar compreende processos que permitam que as mulheres possam viver a vida da forma que almejam, sem balizas impostas pela opressão de gênero e patriarcal, como refletido por Sardenberg (2006). Essa mudança, apesar de gradativa, está ocorrendo conforme apontam os dados do Censo Agropecuário. Em 2006, havia sete estabelecimentos dirigidos por mulheres com formação no ensino superior completo no município de Santa Helena (IBGE, 2006). Em 2017 esse número dobrou, e atualmente são 14 mulheres que dirigem estabelecimentos agropecuários com ensino superior completo (IBGE, 2019). Essa realidade também é encontrada no cenário do território brasileiro, a começar pelo número de estabelecimentos agropecuários dirigidos por mulheres, que contabilizavam 656.255, em 2006, e atualmente somam 946.075, um aumento na taxa de 31% para o período (IBGE, 2006, 2019).

Tais resultados vão ao encontro da análise e projeção que os participantes apresentam ao analisar a vida adulta no passado, a realidade atual e a projeção, especialmente para fillhos(as) e netos(as). Após todas as atividades realizadas, ao fim do encontro, as mulheres apresentaram postura distinta, com entendimentos compartilhados sobre a necessidade de as filhas estudarem e poderem escolher seu destino dentro das condições disponíveis, uma vez que as regras que orientavam o futuro no passado as regem com menor intensidade quando comparadas com suas mães e avós.

CONCLUSÕES

A hipótese norteadora da observação participante resultante do projeto de pesquisa é a de que, quando dadas as oportunidades de coconstruir ou coproduzir soluções de maneira participativa e em um ambiente propício, as mulheres historicamente marginalizadas no campo conseguem articular e expressar seus desafios e visualizar futuros desejáveis, incluindo caminhos para alcançar esse futuro de maneira livre e informada. Os resultados permitem confirmar essa hipótese, na medida em que as mulheres vivenciam e executam essas premissas nos espaços de diálogo estabelecidos.

O uso de metodologias participativas para estabelecimento de espaço de coprodução de conhecimento tem cultivado importantes sementes, que fomentam reflexões nos núcleos familiares e, especialmente, nas mulheres rurais a respeito do seu protagonismo e importância. Romper com crenças e padrões socioculturais é desafiador, e nosso desafio é incentivar novas formas de olhar o protagonismo feminino em meio ao contexto rural.

Embora a preocupação central, ao longo desta discussão, seja a de explorar o potencial das redes de diálogo como ferramenta de superação do lugar de marginalização ocupado por elas na estrutura rural, é importante esclarecer que as relações sociais e de gênero não são estáticas e hierarquizadas nesses contextos rurais, uma vez que se modificam conforme aspectos sociais e culturais. Notoriamente, a estrutura patriarcal enraizada no meio rural faz com que as mulheres estejam submetidas a questões como invisibilidade de sua força de trabalho, ausência de tomada de decisão, bem como a fatores de acesso à educação e até mesmo de casamento, mas seria errôneo as análises se limitarem a oprimidos e opressores. Portanto, as recomendações são para o fomento de ações e políticas que propiciem espaços para que as mulheres possam ressignificar, por meio da coprodução de conhecimento, seu papel na sociedade e no núcleo familiar. Mais do que isso, a necessidade desse diálogo ocorrer, inclusive, com os homens que, devido às estruturas históricas que os orientam, as incentivam a permanecerem na situação de invisibilidade do seu valor produtivo e reprodutivo.

As ações de extensão nas universidades têm possibilitado o reconhecimento da UTFPR em ações que visam atuar em problemas reais, demonstrando que o profissional agrônomo que atua em ações de extensão participativa é diferenciado na medida em que tem olhar holístico sobre o rural ao reconhecer a importância de aspectos socioculturais e de categoriais sociais produtivas comumente marginalizadas e invisibilizadas.

AGRADECIMENTOS

Agradecemos ao Centro de Referência de Assistência Social (Cras) de Santa Helena/PR, em particular às assistentes sociais Andreia Henrichs e Nágila Goeller, e à UTFPR a bolsa concedida. Agradecimento especial às mulheres rurais e suas famílias, que aceitaram participar das oficinas e compartilhar suas histórias conosco.

Este trabalho teve o apoio do Projeto INCT/Odisseia-Observatório das dinâmicas socioambientais: sustentabilidade e adaptação às mudanças climáticas, ambientais e demográficas (chamada INCT – MCTI/CNPq/Capes/FAPs n.16/2014), com suporte financeiro do Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) processo 465483/2014-3; Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (Capes) processo 23038.000776/2017-54; e Fundação de Apoio à Pesquisa do Distrito Federal (FAP-DF) processo 193.001.264/2017.

NOTAS

[1] Particularmente, a ideia de realizar o projeto de extensão que culminou na observação participante desta pesquisa é fruto de uma demanda local, diante da existência de grupos de mulheres rurais sendo assistidas por organizações preparadas para amparo psicossocial, aliada ao interesse das estudantes e docente envolvidas na ação.

[2] Cornelius Castoriadis cunhou o conceito de imaginário social, comumente utilizado para expressar representações sociais enraizadas nas instituições que orientam as sociedades. Para mais informações, consultar Rodrigues (1998).

[3] A atividade envolveu a realização de cálculo do valor financeiro do trabalho das mulheres rurais, por meio de levantamento de todas as atividades realizadas por elas, entre as quais foram elencadas: preparar as refeições, realizar a limpeza da casa (do lar), lavar e passar roupa, cuidar de filhos/netos, cuidados com a horta e pequenos animais, etc. Após elencar todas as atividades que exercem, foi atribuído um valor estimado que seria pago a uma pessoa que realizaria a atividade correspondente utilizando como hipótese a ausência da mulher, chegando a uma estimativa do valor monetário do trabalho doméstico, comumente invisibilizado nos núcleos familiares.

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In this second edition of 2021, the Journal ***Sustainability in Debate - SiD*** warns about the need for more collective intelligence and actions. The urge is to cope with the various climate disasters observed in recent months and expected to be more frequent with global warming. Despite the technological and scientific advances in climatology, only predicting extreme events, such as heatwaves in Canada and torrential rains in China, do not avoid socioeconomic and environmental impacts. Thus, more coordinated action and commitment to implementing adaptation and mitigation measures to climate change are necessary. Besides the many lessons the Covid-19 pandemic gave us, the 2021 climate disasters also need to be seen as a lesson.

This edition of SiD presents a 10-article section Varia. They deal with the following topics: water crisis, photovoltaic energy, water footprint of food, scenarios for biodiesel expansion, resilience of agroextractive settlements, historical influence of ancient societies concerning water management, the concept of the Anthropocene, university social responsibility analysis, the impact assessment based on indicators of benefits of agroecological markets, and networks of dialogue as a tool for recognition of rural women.

Nessa segunda edição de 2021, a Revista Sustainability in Debate - SiD, em seu editorial, alerta sobre a necessidade de mais inteligência coletiva e ações para o enfrentamento dos diversos desastres climáticos observados nos últimos meses, e previstos como mais frequentes com o aumento do aquecimento global. Apesar dos diversos avanços tecnológicos e científicos na área de climatologia, somente prever os impactos extremos, como as ondas de calor extremo no Canadá e chuvas torrenciais na China, não evitam os impactos socioeconômicos e ambientais, sendo preciso mais ação coordenada e compromisso com a implementação de medidas de adaptação e mitigação às mudanças climáticas. Para além das muitas lições que a pandemia da Covid-19 vem deixando, os desastres climáticos de 2021 também precisam servir como lição.

Nessa edição da SiD são apresentados 10 artigo na seção Varia, que tratam sobre os seguintes temas: crise hídrica, energia fotovoltaica, pegada hídrica da alimentação, cenários para expansão de biodiesel, resiliência de assentamentos agroextrativistas, influência história das sociedades antigas em relação à gestão de águas, conceito do Antropoceno, análise de responsabilidade social universitária, avaliação de impacto baseada em indicadores de benefícios de mercados agroecológicos, e redes de diálogo como ferramenta de valorização das mulheres rurais.

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