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The Interconnections between Environment and Health in Cross-border Regions: Contributions to Public Policies

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Abstract: This work sought to analyze the health and environment in the Brazilian municipalities that make up the Frontier Strip (FS), considering the unique challenges of managing these in such territory. For this purpose, the association between them was studied by collecting and analyzing secondary data, using descriptive statistics, mapping, and cluster analysis. The main results demonstrated the lack of public policies, particularly for environmental and health issues in activities of municipal border governments, and the discussions that incorporate intersectionality in planning are even more limited. Of the 94.7% of municipalities analyzed, 53.6% presented an average performance on the environmental issue, and 81.3% a low or very low one on health, probably due to the fact that environmental aspects have gained more attention in the context of Brazilian FS compared to health ones. Finally, the study points out the implications of these results, which can subsidize public policies.

Keywords: Border Region, Public Policy, Public Health, Environmental Health, Sustainable Development.

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1 Introduction

Long before the COVID-19 pandemic ravage the world and strongly hit Brazil, concerns were already raised regarding the vulnerabilities of health and environmental aspects in the cross-border regions (PÊGO et al., 2020). Over the past two decades, major advances have been made in creating research capacity to address the intersection between health and the environment in low- and middle-income countries, where, through these advances, infrastructure, governance, and human capital have been improved (REIDPATH; ALLOTEY, 2020). However, in pandemic times, the efficiency of the territorial management in these countries may weaken. In this context, policymakers have several tools to enable social interventions.

These interventions are often used without empirical evidence, based on a confusing and often inconsistent combination of data, thus reducing the chance of building effective public policies (HAUSHOFER; METCALF, 2020). In this sense, the use of topic-specific indicators is relevant as a complementary resource for public management, since they are easy to manage and methodologically apply, and provide rapid communication of results and analytical congruence.

Therefore, it is essential to analyze these issues in a border context, because borders (territorial, river, air, sea, and lake), as a nation's entry spots, have received greater attention from governments worldwide. In view of scenarios of migratory and pandemic crises, the importance of research to support decision-making is highlighted (PÊGO et al., 2020).

The Brazilian territorial border, in particular, also known as the Frontier Strip (FS), is characterized by its 150 kilometers (km) of width from the international border; it is significant in the national territory, with 588 municipalities along 15.9 thousand kilometers of extension, and it borders ten of the twelve countries of South America (except for Chile and Ecuador), and it has sub-regional peculiarities based on its different biomes and sociocultural formations (BRAZIL, 2015). Moreover, these territorial, geographical, and social characteristics mean that the FS is an environment of pressing challenges, so that health and environmental conditions are also special (KRÜGER; DANTAS; CASTRO, 2018).

Finally, the FS contains the largest areas of environmental preservation, including the Amazon and the Pantanal, and, in contrast, a flow of foreign migrants who take advantage of public services along with the local population, without necessarily co-financing by their country of origin (MELLO; VICTORA; GONÇALVES, 2015). Regarding cofinancing, border municipalities suffer from the conflict between the right to health and the non-registration of immigrants in the Unified Health System (SUS), having to keep the health service demand and supply relationship in constant development (BARBIERI, 2007).

Due to these challenges and the insufficient public actions in these areas, the FS has become characterized by numerous problems, because in addition to long-standing environmental and health problems, it has a poor socioeconomic infrastructure that is unable to subsidize a sustainable development process (GADELHA; COSTA, 2007). After the demand for interventions was acknowledged, this region became the target of a

series of public policies, mostly between 2000 and 2014 (KRÜGER; DANTAS; CASTRO, 2018). However, public actions in health, for example, were completed with no analysis of their possible results and implications for other sensitive areas in the region, such as the environment BARBIERI, 2007; KRÜGER et al., 2017).

In this process, the post-2015 Agenda, expressed through the Sustainable Development Goals (SDGs), highlights the intersectionality and governance dimensions expressed in the territory for its development (GALLO; SETTI, 2014), listing the need for integrating governance mechanisms (SDG 17) capable of impacting all other goals in the Agenda, not just health-related aspects (SDG 3). Moreover, according to a WHO study, 101 diseases analyzed are significantly related to the environment, and, notably, 57% of all diarrhea diseases are attributed to environmental factors (PRÜSS-ÜSTÜN et al., 2016).

In view of this demand for integration between health and environment in public activities aimed at the FS and the absence of academic studies on the topic, this paper aimed to analyze the behavior of the main health and environmental indicators of border municipalities, as well as its regional patterns and the correlation between the areas. Thus, our specific goals were to: characterize the health and environment landscape based on indicators that are close between the areas; correlate possible proximity between them and assess the groupings formed by the municipalities of border regions in terms of health and the environment.

With these objectives in mind, the paper structure was defined in five sections. The first presents the context around the topic, including the justification and objectives established for the research. The second section comprises the theoretical framework built on the determinants of the health-disease process, human and environmental health, the National Environmental Health Policy, and the relevance of assessment frameworks for public decisions in border areas. Then the third part presents the methodological choices regarding the indicators selected to operationalize the variables, as well as the data collection and analysis procedures. After the method is applied, section four sets out the results obtained and the discussions arising from the analyses. Finally, section five covers the main conclusions, limitations, and proposals for future studies on the subject.

With this scope, the paper contributes to the theoretical landscape by discussing the interconnections between health and the environment. In addition, the literature promoted the selection of thematic indicators that operationalized the dimensions proposed in the study, the results of which are presented herein in choropleth maps unprecedented on the FS subject, corroborating the proposed methodological framework. Also, regarding the practical aspect of the work, the analyses carried out provide data that indicate trends and communicate evidence that can support political decision-makers in their public health and environmental actions in Brazilian border municipalities.

2 Theoretical review

2.1. Health-disease process determinants

In Brazil, the Unified Health System (SUS), established by the 1988 Federal Constitution and consolidated by laws No. 8,080 (BRASIL, 1990a) and No. 8,142 (BRASIL, 1990b), is based on the principle of health as a citizen's right and State's duty (BRASIL, 1988). SUS is the greatest social inclusion policy in the country and has a universal scope to ensure care at primary, specialized outpatient, and hospital care levels (MENDES, 2013; PAIM et al., 2011).

In this sense, it is key to understand that health, both individually and collectively, is influenced by intrinsic risk factors and external factors, that is, by a complex set of social, political, economic, and environmental aspects (DORA et al., 2015; RANTALA; BORTZ; ARMADA, 2014; VIACAV et al., 2012). According to Viacava et al. (2012), health-disease processes can be grouped into three groups: (i) environmental determinants: physical, chemical, and biological aspects of the environment; (ii) socioeconomic determinants: demographic, socioeconomic, and contextual characteristics; (iii) behavioral and biological determinants: attitudes, practices, beliefs, behaviors, and individual biological factors.

In the context of environmental determinants, poor environmental conditions are important factors that induce disease generation (PRÜSS-ÜSTÜN et al., 2016). Despite its importance, Dora et al. (2015) claim that environmental determinants of health have been historically neglected compared to the others so there is a pressing current demand for further discussions that recognize health as a result of sustainable development.

Therefore, these determinants must be better understood and investigated, so that they are discussed and included in the political agenda, thus receiving due attention (GALLO; SETTI, 2014; PAIM et al., 2011). In this sense, it is understood that the relationship between health and the environment is reciprocal, in the sense that both public policies can influence each other, with different impacts on society (DUBOIS; ST-PIERRE; VERAS, 2015; PRÜSS-ÜSTÜN et al., 2016).

2.2. Human health and environmental health: interface and relevance

Environmental health has an influence on the production of scientific knowledge and the drafting of public policies. It also relates to the actions referring to the interaction between human health and the natural and anthropic environment with the purpose of increasing the quality of life under the principles of sustainability (BRASIL, 2021).

The interface between health and the environment involves different factors that interfere with their own conditions in a complex way, with different levels of influence. It includes preponderant aspects that have an impact on the quality of human life and environmental conditions and has a direct effect on the maintenance of life on the planet (LÉVI, 2020).

Research on how the environment benefits human health through the regulation of ecosystem services, for example, lacks specifications on the relationships involved (HOSSAIN et al., 2021). Notably, the importance of the fundamental links between environmental and human health is increasingly recognized in the development of local, regional, and global policies. Consequently, we see a growing need to develop more knowledge about how interactions between the environment and people are important for human health and the maintenance of life on the planet (MARSELLE et al., 2019).

2.3. National Environmental Health Policy (PNSA)

The interconnection of health and environmental actions reinforces the need for a national policy that guides complementary and interdependent sectoral actions, combining and preparing a set of initiatives that focus on determinants and constraints that influence human life (USA, 2021). The protection and promotion of human health, along with environmental protection, and the search for more sustainable alternatives, suggest a common agenda for environmental health, considering an important benchmark: the National Environmental Health Policy (PNSA).

The consensus reverberated from the I Seminar of National Environmental Health Policy, in 2005, which highlighted the importance of intersectoral and transdisciplinary practices, pondering on human health and ¸the ecological, geological, and social relations of man with the environment. It also demonstrated concern about human well-being and quality of life, without disregarding the search for sustainability (BRASIL, 2009). However, Brazil has not yet formalized its environmental health policy (FAUSTINO, 2021). Since 1998, the Ministry of Health (MS) has managed efforts that are part of the process of building this policy, supported by different organizations (RADICCHI, 2009). In view of this, the Brazilian MS has been working through an Environmental Health Surveillance System, seeking the improvement of a model of action focused on the SUS, establishing competencies that support the implementation of actions related to human health,environmental degradation, and contamination (BRASIL, 2009).

The PNSA should seek the protection and promotion of human health, while protecting the environment from harmful interventions through a set of ¸specific actions integrated with the different levels of government and civil society, strengthening public participation and engagement (RADICCHI, 2009). By integrating public policies, the PNSA seeks to: aggregate and support players, solutions, and interests; promote actions at international, regional, state, and municipal levels; cooperate technically and financially with other players; promote and seek scientific support and research to act; create assessment mechanisms ¸for health impacts related to development projects, options ¸and actions (BRASIL, 2009).

2.4. Assessment frameworks for border regions

The need for systematic approaches to assess how environmental and health issues interact, including definition and measurement through indicators, is recognized by the literature (MAPAR et al., 2020; MAPAR et al. 2017). Methodological frameworks can provide well-structured and easy-to-reproduce foundations and guidelines, ensuring that all relevant steps in this process are included in the assessment (RAMOS, 2019). In this process, the indicators provide concrete help to the work of analyzing the behavior of each topic analyzed (SINGH et al., 2009).

The methodological framework can be used to assess the existing sectoral policies (*ex post*) and draft new policies (*ex ante*) (RAMOS, 2019), as well as to understand the impact of the efficiency and effectiveness of management strategies that contribute to sustainable development (ZINKERNAGEL; EVANS; NEIJ, 2018), to be implemented by the governments of the municipalities studied.

Thus, one of the major challenges lies in the process of developing a common framework that assesses environmental and human health in border regions (PEZZOLI et al., 2014), considering federal actions, but applying the logic of municipal planning and management. This is necessary because, although cross-border regions have in common the environment and population flows, they have singular legislative structures and health infrastructures (PÊGO et al., 2020).

In addition, when analyzing the FS, it is possible to see differences in the factors of the border sub-regions, which indicates the need to survey local data in order to have assessment frameworks to support public decisions that are aimed at specific applications and at not the national border as a whole (KRÜGER et al., 2017).

3 Methodology

The research method involved defining a methodological framework, including the following resources: i) defining the study area; ii) selecting the dimensions and indicators to be included; iii) collecting and processing the selected data; e, iv) presenting and discussing the results found. The data were collected from two databases, including the National Sanitation Information System (SNIS) and the Informatics Department of SUS (Datasus).

The research design, as shown in Figure 1, demonstrates the study steps. First, the research gap was determined based on the literature. Based on the indicators selected from it, a conceptual framework was developed to support the analysis of the study dimensions.

Figure 1 – Descriptive methodological framework of the stages followed in the research development

Source: Prepared by the authors, 2022.

The research combined the exploratory, quantitative and descriptive-analytical approaches, covering the 588 Brazilian municipalities that make up the national FS (BRASIL, 2015; COOPER; SCHINDLER, 2011). Thematic indicators were selected from the literature to operationalize the "environmental management" (DORA et al., 2015; RANTALA; BORTZ; ARMADA, and "populational health conditions" (ANDRADE et al., 2021; DIAS; SANTOS NETO; ANDRADE, 2017; VIACAVA et al., 2012) dimensions. To that end, we used indicators from 2016 because this was the most recent period of communication of these metrics, with the same temporality between the data used (BRASIL, 2018a, 2018b).

The definition of indicators can be based on theoretical models in which indicators are seen as objective tools. However, the selection and processing of these indicators are always objective, directly influencing their practical use (SPANGENBERG, 2018). Thus, the study sought to, through a literature review, highlight some dimensions that reflect the current social debates and priorities in the Brazilian FS. In this case, the indicators adopted can be used to draft/maintain public policies, communicating relevant results to stakeholders, such as communities or residents of these areas (WONG, 2006).

The indicators chosen must be specific and sectoral, measurable or observable, and the data made available to the general public. However, different conceptual understandings may lead to the selection of different indicators, which in turn will lead to differences in the resulting performance (WILSON; TYEDMERS; PELOT, 2007). An important criterion for selecting indicators is that the total number of indicators should be limited and concise (NIEMEIJER; GROOT, 2008; SCIENCE FOR ENVIRONMENTAL POLICY, 2015), providing a manageable workload. In practice, most indicators for municipalities are selected based on data availability, as demonstrated by Keirstead e Leach (2008) e Lehtonen, Sébastien e Bauler (2016).

Thus, in view of the combination of indicators under the main topic of basic sanitation and the scarcity of environmental data on municipalities, the choice of these indicators was based on the availability of information. In the environmental sphere, the following indicators were used from the National Sanitation Information System (SNIS) (NIS) (BRASIL, 2018b) based on the literature (DORA et al., 2015; RANTALA; BORTZ; ARMADA, 2014):

- Index of full water provision: Describes the full coverage of the water supply network.
- Index of water loss in distribution: Represents the percentage of water lost in the distribution by municipalities
- Garbage collection coverage rate: Measures the proportion of the population with access to garbage collection services.

In addition to the data availability criterion, for the health dimension, we collected indicators with greater sensitivity and possible relation to environmental determinants (ANDRADE et al., 2021; DIAS; SANTOS NETO; ANDRADE, 2017; VIACAVA et al., 2012) from the Ministry of Health Information Systems, the Department of Informatics of the SUS (DATASUS), and the Health Information section of TABNET (BRAZIL, 2018a), namely:

- Venomous animal accident rate: displays the rate of accidents caused by venomous animals
- Hospitalization rate (ICD-10): expresses the number of hospitalizations that represent the ICD-10 groups.
- Preventable cause death rate - children under 5 years (ICD - 10): displays the number of hospitalizations that represent the ICD-10 groups due to preventable causes and in children up to 5 years old.

For analysis purposes, we applied the data normalization method, as suggested by Singh et al. (2009). Thus, the indicators collected were transformed into rates, providing a common unit of measurement to facilitate comparative analyzes between the municipalities studied.

Equation 1

Standardization of health indicators

$$Taxa = \frac{Valor\ do\ indicador}{População\ estimada}\ x\ 1000$$

In this study, the indicators of both dimensions (environmental and health) received equal weights because they were considered equally important in characterizing the FS situation, with no need for weighting techniques.

After collection, the data was organized on a single base using Microsoft Excel. First, the outliers were identified, and 31 municipalities were excluded because they had none of the data on the selected environmental indicators and did not have at least one of the health indicators. After this first processing, we identified some municipalities with environmental data available, but without some of the health indicators. To process them, we used the statistical technique of Z-Score standardization, whose objective is to normalize observations with a standard deviation above or below the population average; then the sample was ready for analysis (FÁVERO; BELFIORE, 2017; HAIR et al., 2005).

After the base was thus organized, the analyzes were carried out using descriptive statistics techniques, mapping, correlation analysis, and cluster analysis. These techniques were applied using the IBM SPSS Statistics statistical package, version 17.0, and the geoprocessing QGIS software, version 2.14. During the discussions, the information units (municipalities) were grouped into sets called "arcs", following the specifications and nomenclatures of the study developed for the federal government. Thus, the FS was grouped into three arcs according to its territorial and population specificities, with the following states in each sub-region: North Arc (Amapá, Pará, Roraima, Amazonas, and Acre); Central Arc (Rondônia, Mato Grosso, and Mato Grosso do Sul); and South Arc (Paraná, Santa Catarina, and Rio Grande do Sul) (BRASIL, 2015).

In addition, the mapping technique was used to represent the results of the research in terms of geographical distribution. To this end, we used the data referring to the names of the municipalities and their respective reference codes from the Brazilian Institute of Geography and Statistics (IBGE, 2016). A set of choropleth maps was elaborated, with each color representing a data classification to portray the scenario of environmental and health indicators in the FS. The five data classes ("very low", "low", "medium", "high", and "very high") were created by the geoprocessing software, and the indicators were separated into quintiles.

In order to understand the pattern of association between the different variables, we

decided to carry out correlation analyzes. This technique provides a numerical summary of the strength of the linear relationship between two variables, that is, the degree to which they move together, as well as the direction of this relationship, which can be positive (as one variable increases, so does the other) or negative (as one variable increases, the other decreases) (CORRAR; PAULO; DIAS FILHO, 2007; FÁVERO; BELFIORE, 2017; LATTIN; CARROL; GREEN, 2011). The correlation coefficients are the measurements used to reveal the magnitude and direction of the relationships between variables and they include: Pearson's coefficient and Spearman's (CORRAR; PAULO; DIAS FILHO, 2007; FÁVERO; BELFIORE, 2017).

At the end of the study, the principal components analysis (PCA) was used to create 2 indexes, an environmental one (synthesizing the 3 indicators used for the environment), and one for health (synthesizing the 3 indicators used in health). To construct the "environmental index", we used the inversion processing in the "Index of water loss in distribution" to correct the reversed polarity in relation to the other 2 environmental indicators. Finally, to group the municipalities according to their homogeneities and separate them according to their heterogeneities, based on the health and environmental indicators, we carried out a cluster analysis (CORRAR; PAULO; DIAS FILHO, 2007; FÁVERO; BELFIORE, 2017; LATTIN; CARROL; GREEN, 2011) in order to create conglomerates with similarities among municipalities (CORRAR; PAULO; DIAS FILHO, 2007; FÁVERO; BELFIORE, 2017). The results are as shown below.

4 Results and Discussions

4.1 Descriptive analysis of border municipalities

In the context of data analysis, we chose to initially present the results regarding the general profile of the border municipalities in relation to the indicators selected, as shown in Table 1.

Table 1 - Descriptive statistics of border municipalities

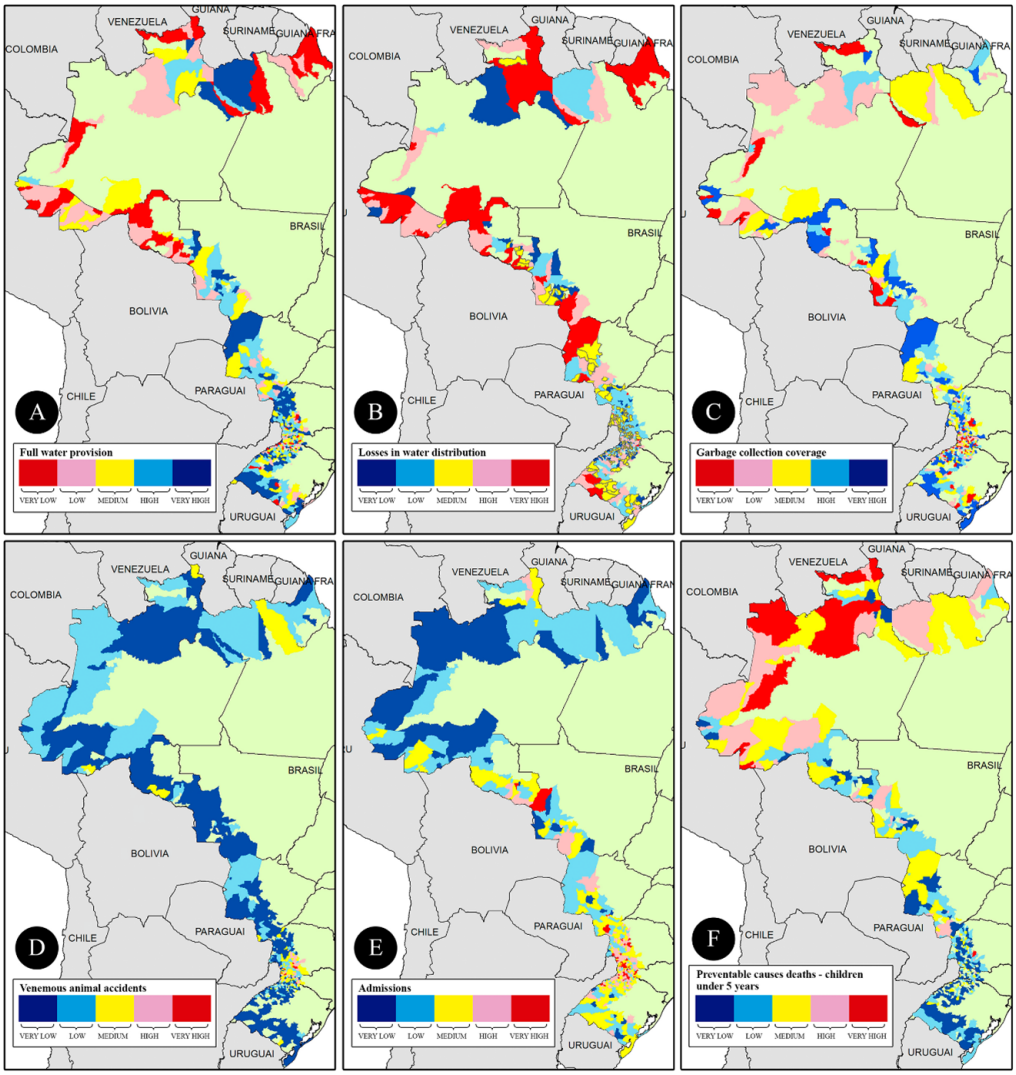
Descriptive statistics	FS Arcs	Index of full water provision	Index of loss in distribution	Garbage collection coverage rate	Venomous animal accident rate	Hospitalization rate	Preventable-cause death rate in children under 5 years
Range	North	0.96	0.91	0.77	3.41	119.95	1.77
	Central	0.82	0.8	0.62	3.05	121.19	0.75
	South	0.81	0.73	0.86	13.03	224.09	1.06
Minimum	North	0.04	0	0.23	0.08	4.19	0.05
	Central	0.18	0	0.38	0.09	22.65	0.05
	South	0.19	0	0.14	0.04	3.63	0.03

Maximum	**North**	1	0.91	1	3.49	124.13	1.83
	Central	1	0.8	1	3.14	143.84	0.8
	South	1	0.73	1	13.07	227.72	1.09
Mean	**North**	0.42	0.53	0.61	1.15	53.18	0.47
	Central	0.72	0.32	0.76	0.73	63.5	0.33
	South	0.72	0.29	0.65	2.15	83.07	0.23
Standard deviation	**North**	0.22	0.24	0.22	0.76	25.85	0.38
	Central	0.18	0.18	0.17	0.62	24.29	0.17
	South	0.23	0.14	0.23	2.32	25.71	0.14
Variance	**North**	0.05	0.06	0.05	0.58	668.35	0.15
	Central	0.03	0.03	0.03	0.38	590.06	0.03
	South	0.05	0.02	0.05	5.38	660.97	0.02

Source: Prepared by the authors, 2022.

Among the data analyzed, it is important to point out that the North Arc has, on average, the worst indicators related to the environment in comparison to the municipalities that make up the border regions of the Central and South Arcs, with a low level of full supply (0.42) and waste collection coverage (0.61), and a high level of loss in distribution (0.53), also shown in Figures 2A, 2C, and 2B, respectively. Moreover, the particularities of the North Arc in terms of long distances between urban areas contribute to and reinforce the isolation and precarious conditions that are quite present in this region (NUNES, 2018).

Figure 2 - Environmental (A, B, and C) and health (D, E, and F) landscape in the border municipalities



Source: Prepared by the authors, 2022.

On the other hand, the Central Arc stands out positively for its average full water supply (0.72) and garbage collection coverage (0.76) and has the lowest number of accidents due to venomous animals (0.73) (Figures 2A, 2C, and 2D, respectively). The South Arc has the same average as the Central Arc in full water supply (0.72) and it stands out for its lower average of loss in water distribution (0.29) and deaths from preventable causes in children under 5 years of age (0.23) (Figures 2A, 2B and 2F, respectively); however, it has higher results in the health indicators of accidents due to venomous animals (2,15) and hospitalizations (83,07) (Figures 2D and 2E) (PEITER et al., 2013).

To complement that, the standard deviation and variance reflect the same results since in both areas (environment and health), the greatest variations and asymmetries of the sample are in regions of the North and South arches, while the region of the Central Arc has more homogeneous municipalities in this scenario. This situation reflects that, although the South arch has better indicators, in general, compared to the North Arc, inequality in both regions is noticeable (GIOVANELLA et al., 2007; KRÜGER et al., 2017) in view of the disparity in the water supply.

As for the health landscape, in particular, based on the 2D map, it is possible to see that there is greater homogeneity in the results, since most of the municipalities in all the border arcs have very low or low performance regarding accidents caused by venomous animals, with the exception of some municipalities in the South Arc, which present average, high or very high performance. Regarding map 2E, there is a predominance of average performance in the Central and South Arcs in hospitalization rate, unlike the North Arc border region, which has a greater number of municipalities with indicators in the very low or low range. Finally, when analyzing map 2F, deaths from preventable causes in children under five, it is evident that the border region of the North Arc has municipalities with high and very high indicators, which represents a worse health situation in comparison with the border regions of the Central and South Arcs.

Thus, we can highlight that the border region of the North Arc has lower hospital admissions rates and higher preventable-cause death (children under 5) rates than those of the border regions of the Central and South Arcs. These results may be due to deficiencies in socioeconomic infrastructure and demographic characteristics of this arc since the worse the socioeconomic infrastructure of the municipalities, the fewer opportunities and beds for hospitalization, and the greater the precariousness in access to health services, the greater the predominance of infectious diseases, which directly affect deaths (BRUNIERA-OLIVEIRA et al., 2014; GADELHA; COSTA, 2007).

In the specific case of the FS, there are several aspects that collaborate to the worsening of the situation, among them: the difficulty of access to hospital services due to the environmental formation of the regions and historical precariousness of infrastructures; a limited number of hospital beds; social vulnerability in the region; and the demographic profile, particularly in the North and Central Arcs, with emphasis on traditional peoples (indigenous, riverine, and quilombola peoples), as well as migrants (PÊGO et al, 2019).

4.2 Analysis of correlation of indicators

In this context, we generated the Pearson and Spearman coefficients, as shown in Table 2. From the results, we found that, of the 30 coefficients calculated (15 Pearson and 15 Spearman), 23 were statistically significant. Among these, 2 had 0.05 ($\alpha = 0.05$) significance, and all the other had 0.01 ($\alpha = 0.01$).

Table 2 - Pearson's correlation coefficients for environmental and health indicators

Correlations						
	1	2	3	4	5	6
1- Index of full water provision		-.249**	.498**	-.124**	.140**	-.296**
2- Index of loss in distribution	-.222**		.110*	-0.46	-.172**	.187**
3- Garbage collection coverage rate	.461**	.095*		-.301**	-0.84	-.319**
4- Venomous animal accident rate	-.181**	-.0.32	-.323**		.248**	0.54
5- Hospitalization rate (ICD-10)	.124**	-.138**	-.088	.278**		-.176**
6 - Preventable cause death rate in < 5-year old (ICD-10)	-.185**	-.094	-.281**	0.76	-.162**	

Source: Prepared by the authors, 2022.

It should be noted that, in comparison to the others, the most intensely associated variable pair in "water supply index" and "garbage collection coverage rate", with a positive and moderate correlation, with a significance level of 0.01. Therefore, we verified that the coefficients move in the same direction, so that, by increasing the rate of water supply, there is also a growth in the coverage of household solid waste collection rates. Thus, the coefficients may signal similar profiles of environmental management in the municipalities, that is, the border municipalities with greater investments in an adequate performance of water supply also have a greater reach of waste collection management services. The border municipalities with the most difficulties in water supply also have the greatest challenges in waste management and are, therefore, more vulnerable to the health problems resulting from this scenario (SILVA, 2017).

We can highlight the significant negative correlations between the environmental indicator "garbage collection coverage rate" and the health indicators "venomous animal accident rate" and "deaths in children <5 years old." It should be emphasized that these coefficients are low in intensity, between 0.2 and 0.3, and the strongest one observed was Spearman's, for the association between garbage collection and accidents due to venomous animals (-0.322).

Without defining the cause and effect relationship, the negative direction of the correlation signals an inverse association between the indicators; thus, an increase in the coverage of household waste collection in border municipalities may be associated with lower accident rates due to venomous animals and hospitalizations of children in the region; similarly, lower availability of waste collection service is associated with an increase in the health problems listed. Still in the context of waste collection, there

is no significant statistical relationship between this environmental indicator and the hospitalization rate (ICD-10). These results demonstrate that investments in improving solid waste management processes can lead to a reduction in children's hospitalization and a possible reduction in accidents due to venomous animals (ANGNES et al., 2013).

Another result regarding the health-environment relationships concerns the significant negative coefficients, of low-intensity, between the full water supply index and the preventable-cause death rate in children (-0.296 for Pearson's and -0.185 for Spearman's). In addition, similar coefficients were obtained between the full water supply index and the rate of accidents due to venomous animals (-0.124 in Pearson's and -0.181 in Spearman's). This result corroborates the discussions on health benefits from resources directed to sanitation and drinking water, in view of the influence of these environmental conditions on disease incidence (PRÜSS-ÜSTÜN et al., 2016).

Finally, the correlations presented in Table 2 are relevant for the public management of the region under study, emphasizing the importance of the interrelationship between the environment and health, since investments in environmental management can also yield positive results in health (DUBOIS; ST-PIERRE; VERAS, 2015).

4.3 Cluster analysis based on the environmental and health factors created

In view of the analyzes presented in the previous section, it was possible to highlight the differences that characterize the municipalities of the FS regarding their environmental management (ANGNES et al., 2013) and the variability in the scenario of the health conditions of the population living in these areas (PÊGO et al., 2020). In order to advance the discussions to meet the research objectives, based on the purpose of integration between areas, this step seeks to group municipalities according to their similarities in health and environment.

Based on the two factors created through the principal component analysis (PCA), which represented the indicators of "environment" and "health", we were able to create 4 clusters with characteristics in common and divide by the municipalities' participation in the border arcs, as shown in Table 3:

Table 3 - Cluster analysis

Municipalities		Population**	North Arc*	Central Arc*	South Arc*	Total	Mean - E.M***	Mean - Health***
Group 1	197	3,070,048	38.6%	12.2%	49.2%	35.4%	2.11	3.44
Group 2	256	7,528,021	3.5%	16.4%	80.1%	46.0%	3.85	3.82
Group 3	102	767,536	1.0%	1.0%	98.0%	18.3%	2.62	5.48
Group 4	2	5,646	0.0%	0.0%	100.0%	0.4%	0.70	7.00
Total	**557**	**11,371,251**	**15.4%**	**12.0%**	**72.5%**	**100.0%**	**3.00**	**4.00**

* Percentage of municipalities in each region by grouping.

** Total population of the municipality IBGE (2016) by grouping.

*** Mean in relation to environmental and health factors.

Source: Prepared by the authors, 2016.

As can be observed in Table 3, the conglomerates generated have similar characteristics between the municipalities that compose them. Thus, Group 1 is the second most populous group among the conglomerates and it also has the second largest number of municipalities, represented mainly by the municipalities of the South and North Arc in its composition.

As for the health and environmental indicators, Group 1 presents a lower-than-average performance, with the worst performance in health (3,44) among all other groups.

Group 2, on the other hand, stands out for having the best performance in the environment (3.85) in relation to the other groups. In contrast, it presents the second worst performance in health, better only than group 1. It should be noted that group 2 is the most populous of clusters and comprises the largest number of municipalities.

Group 3 is the third most populous cluster, thus with the third largest number of municipalities, represented mostly by the South Arc of border municipalities. Regarding the topics, it has the second best performance in the environment, although below average in comparison with all the border municipalities, it presents the second best performance in health. Finally, group 4, represented only by 2 municipalities of the South region (Paial and Xavantina), has very specific characteristics, with the worst performance in environment, but with a great performance in health. From these analyzes, some notes can be made:

1. There is great intra-regional inequality between the municipalities of the South Arc, with municipalities with high environmental and health performance in close proximity to municipalities in a precarious situation in these sectors (ANGNES et al., 2013; KRÜGER et al., 2017);
2. A large number of the FS municipalities have an environmental performance close to the mean, and a health performance below the mean, as pointed out by Pêgo et al. (2020) when analyzing the FS;

3. The North Arc has a more homogeneous composition regarding the performances, with municipalities essentially represented in group 1, with priority characteristics due to the more precarious environment and health context, which corroborates the possibility of correlation between the reality of these areas under study in the region (BARBIERI, 2007);
4. The municipalities of the Central Arc of the FS, mainly represented in groups 1 and 2, have a performance close to the mean in the environment and below the mean in health.
5. There were no groupings of municipalities in the FS arcs with a performance above the mean in both environment and health;
6. The municipalities of Paial and Xavantina (group 4) present a considerably different scenario between the two sectors, with high performance on health and a very low one on the environment. This specific characteristic demands in-depth analyses and does not represent the general performance of the border municipalities.

It is also relevant to point out that these findings demonstrate not only expressive differences in the health and environmental aspects of the FS arcs but also between the factors under analysis in the municipalities of the same arc. This is in line with the discussions promoted by Nunes (2018), who argued about the importance of greater action by municipalities in decisions and that public policies consider territorial, historical, and socioeconomic references in investment planning.

5 Final Considerations

In view of the contemporary scenario marked by the complexity of demands and socio-environmental problems, which were worsened by the unexpected COVID-19 pandemic, combined with the scarcity of resources, it is necessary to have a commitment to ensure efficiency, efficacy, and effectiveness in public policies. To this end, it is widely accepted that these actions need to be planned, implemented, and assessed in an integrated manner between the two sectors. This finding was also observed in the national FS, which comprises a region of the Brazilian territorial boundary historically known for isolation and socioeconomic and environmental vulnerabilities.

The results presented characterize the diversity of border regions, emphasizing the coexistence of diverse realities and the need for policies to consider territorial peculiarities, with the North Arc standing out with the worst performances.

We can see that most of the municipalities of the Brazilian FS arcs, as well as those with the largest population (groups 1 and 2), have a performance close to the mean in relation to the environment, and below the mean in health. Another highlight is found in the North and Central Arcs. The first had performance below the mean in environment and health, while the Central Arc performed close to the mean in the environment and below the mean in health, demonstrating the demand for specific public policies for conglomerates of municipalities, according to the greatest needs raised.

It should be noted that the research approached these relationships in an exploratory way, so further studies are required to advance and consolidate the discussions. The limitations are derived from the exclusive use of secondary data and the attribute of reliability of the indicators.

In this context, we suggest: (i) conducting new research using qualitative methods, deepening the analytical function of the proposal, increasing understanding of the reality of health/environmental issues in border municipalities; (ii) proposals for comparative analyzes between the FS and the other Brazilian municipalities;(iii) directional studies that expand the group of environmental and health indicators for the FS, including additional attributes that consider the temporal evolution of this landscape, as well as the specificities and regionalities of the research object; and iv) future studies should seek to explore other indicators to verify their possible correlations with the other goals of the Post-2015 Agenda, expanding systemic analyzes of the multiple aspects of sustainable development in the FS.

As for the contribution of the study, the results of the two-dimensional analysis provide important insights for the public management of the municipalities of the region studied, and the choropleth maps were an important Communicator of the situational landscapes. In addition, the methodological framework can be used as an application model, reproduced in different systems. Its application flexibility supports the inclusion of new analytical dimensions and variables to broaden the scope of results and conclusions at different levels.

In this sense, this analysis is a contribution to the set of efforts that have been undertaken in research to minimize adverse situations due to poor infrastructure and uncoordinated actions between countries in cross-border regions, such as in refugee crises, and in the current pandemic scenario, with the proposal of intersectoral actions between the environment and health for more effective results in border regions.

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AMBIENTE & SOCIEDADE 25 anos 25 años 25 years

SciELO

As Interconexões entre Meio Ambiente e Saúde em Áreas Transfronteiriças: Contribuições para Políticas Públicas

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Resumo: O presente artigo buscou analisar os temas saúde e meio ambiente nos municípios da Faixa de Fronteira (FF) brasileira, haja vista os desafios singulares de gestão destes setores neste território. Para isso, verificou-se a associação entre eles por meio de uma coleta e análise de dados secundários, utilizando estatística descritiva, mapeamento e análise de cluster. Os principais resultados demonstraram a carência de políticas públicas setoriais, especialmente para os temas meio ambiente e saúde nas atividades dos governos municipais fronteiriços, sendo ainda mais escassas as discussões que incorporam a intersetorialidade no planejamento. Dos 94,7% municípios analisados, 53.6%% apresentaram desempenho mediano no tema ambiental, e 81.3% baixo ou muito baixo no tema saúde, depreendendo-se que no contexto da FF brasileira, os aspectos do tema ambiental têm ganho mais atenção em comparação com os aspectos da saúde. Por fim, o estudo contribui ao apontar implicações destes resultados capazes de subsidiar políticas públicas.

Palavras-chave: Região fronteiriça, Política pública, Saúde pública, Saúde ambiental, Desenvolvimento sustentável.

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AMBIENTE & SOCIEDADE 25 anos 25 años 25 years

SciELO

Las Interconexiones entre Medio Ambiente y Salud en Áreas Transfronterizas: contribuciones a las Políticas Públicas

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Resumen: Este artículo busca analizar los temas de salud y medio ambiente en los municipios de la Banda Fronteriza Brasileña (FF), dados los singulares desafíos de gestión de estos sectores en este territorio. Para ello, se verificó la asociación entre ellos a través de una recolección y análisis de datos secundarios, utilizando estadística descriptiva, mapeo y análisis de conglomerados. Los principales resultados mostraron una falta de políticas públicas sectoriales, especialmente en temas de medio ambiente y salud, en las actividades de los gobiernos municipales fronterizos, siendo aún más escasas las discusiones que incorporan la intersectorialidad en la planificación. Del 94,7% de los municipios analizados, el 53,6% tuvo un desempeño medio en el tema ambiental y el 81,3% bajo o muy bajo en el tema de la salud, lo que implica que en el contexto de la FF brasileña, los aspectos ambientales han ganado más atención en comparación con la salud. aspectos. Finalmente, el estudio contribuye señalando las implicaciones de estos resultados capaces de sustentar políticas públicas.

Palabras-clave: Región fronteriza, Política pública, Salud pública, Salud ambiental,Desarrollo sostenible

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