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A huge risk of Dengue outbreaks after 2024 autumn flooding in Southern Brazil

Um enorme risco de surtos de Dengue após as enchentes de outono de 2024 no sul do Brasil

Un enorme riesgo de brotes de Dengue tras las inundaciones de otoño de 2024 en el sur de Brasil

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Cintia da Silva Varzim
ORCID: https://orcid.org/0000-0003-0833-143X
Universidade Federal do Rio Grande do Sul, Brazil
E-mail: ufes.cintia@gmail.com
Jaqueline Dilly
ORCID: https://orcid.org/0000-0003-3819-4288
Universidade Federal do Rio Grande do Sul, Brazil
E-mail: jaqueline.dilly@ufrgs.br
Aline Otto Pfeifer
ORCID: https://orcid.org/0009-0006-0090-022X
Universidade Federal do Rio Grande do Sul, Brazil
E-mail: alineopfeifer@gmail.com
Luciana Dalla Rosa
ORCID: https://orcid.org/0000-0002-5047-0014
Universidade Federal do Rio Grande do Sul, Brazil
E-mail: lucianadallarosa@gmail.com
Carlos Eugênio Silva
ORCID: https://orcid.org/0000-0003-4977-9708
Universidade Federal do Rio Grande do Sul, Brazil
E-mail: ceusilva@ufrgs.br
Onilda Santos da Silva
ORCID: https://orcid.org/0000-0003-4806-8285
Universidade Federal do Rio Grande do Sul, Brazil
E-mail: onilda.silva@ufrgs.br

Abstract
The international press recently reported floods in the southern Brazil, specifically in the state of Rio Grande do Sul (RS), during May 2024. These floods caused significant economic losses, affecting the agriculture, industry, and commerce sectors, and displacing thousands of people who lost their homes. A total of 540,188 families were displaced, as 471 of the 497 cities in the state were affected by the storms - equivalent to 94.77% of the total. In addition, floods also provide new breeding grounds for mosquitoes, which consequently increases outbreaks for Dengue virus. This arbovirus causes one of the most human concerning arthropod-borne diseases globally. This work presents an analysis of the Dengue situation in the state of Rio Grande do Sul, and lists the cases of this disease after the floods in the city of Porto Alegre, combining official data, meteorological information and scientific knowledge on the subject. In 2023 1,649,144 Dengue infection were reported, with 1,179 deaths. Comparatively, in 2024, the numbers reached to 6,148,161 with 4,207 deaths by the 25rd week, i.e., by the end of June. In this context, the RS has a 12.66% fatality rate for severe cases, the second highest in the country. Thus, it is crucial to prepare health systems for proper screening and follow-up of potential future patients resulting from the floods. Prevention campaigns and efforts to combat the spread of the *Ae. aegypti* mosquito urgently need to be mobilized through various communication channels by the government, reaching households, with priority given to those located in high-risk areas, especially the recently flooded regions.
Keywords: Arboviruses; Dengue Virus; Flooding; Climate change.

Resumo
A imprensa internacional noticiou recentemente inundações no sul do Brasil, especificamente no estado do Rio Grande do Sul (RS), durante o mês de maio de 2024. Essas inundações causaram perdas econômicas significativas, afetando os setores da agricultura, indústria e comércio, e deslocando milhares de pessoas que perderam suas casas. Um total de 540.188 famílias foram deslocadas, já que 471 das 497 cidades do estado foram afetadas pelas tempestades - o equivalente a 94,77% do total. Além disso, as inundações também proporcionam novos criadouros de mosquitos, o que aumenta, em consequência, os surtos de vírus da Dengue. Este arbovírus causa uma das doenças transmitidas por artrópodes mais preocupantes em todo o mundo. Este trabalho apresenta uma análise da situação da Dengue no estado do Rio Grande do Sul, e faz uma relação dos casos dessa doença após as inundações na cidade de Porto Alegre, combinando dados oficiais, informações meteorológicas e conhecimentos científicos sobre o tema. Em 2023 foram notificadas 1.649.144 infecções por Dengue, com 1.179 mortes. Comparativamente, em 2024, os números chegaram a 6.148.161 com 4.207 mortes até a 25ª semana, ou seja, até o final de junho. Nesse contexto, o RS apresenta taxa de

letalidade de casos graves de 12,66%, a segunda maior do país. Assim, é crucial preparar os sistemas de saúde para o rastreio e acompanhamento adequados de potenciais futuros pacientes resultantes das cheias. Campanhas de prevenção e esforços para combater a propagação do *Ae. aegypti* precisam urgentemente ser mobilizadas através de vários canais de comunicação por parte do governo, alcançando as famílias, com prioridade para aquelas localizadas em áreas de alto risco, especialmente as regiões recentemente inundadas.
Palavras-chave: Arbovírus; Vírus da Dengue; Inundações; Mudanças climáticas.

Resumen
La prensa internacional informó recientemente sobre inundaciones en el sur de Brasil, específicamente en el estado de Rio Grande do Sul (RS), durante mayo de 2024. Estas inundaciones provocaron importantes pérdidas económicas, afectando a los sectores de la agricultura, la industria y el comercio, y desplazando a miles de personas que perdieron sus hogares. Un total de 540.188 familias fueron desplazadas, ya que 471 de las 497 ciudades del estado fueron afectadas por las tormentas, lo que equivale al 94,77% del total. Además, las inundaciones también proporcionan nuevos lugares de reproducción para los mosquitos, lo que aumenta en consecuencia los brotes del virus del Dengue. Este arbovirus causa una de las enfermedades transmitidas por artrópodos que más preocupa a los humanos a nivel mundial. Este trabajo presenta un análisis de la situación del Dengue en el estado de Rio Grande do Sul y enumera los casos de esta enfermedad después de las inundaciones en la ciudad de Porto Alegre, combinando datos oficiales, información meteorológica y conocimientos científicos sobre el tema. En 2023 se reportaron 1.649.144 contagios de Dengue, con 1.179 muertes. Comparativamente, en 2024, las cifras ascendieron a 6.148.161, con 4.207 muertes en la semana 25, es decir, a finales de junio. En este contexto, lo RS tiene una tasa de letalidad por casos graves del 12,66%, la segunda más alta del país. Por lo tanto, es crucial preparar los sistemas de salud para la detección y el seguimiento adecuados de los posibles futuros pacientes resultantes de las inundaciones. Campañas de prevención y los esfuerzos para combatir la propagación del *Ae. aegypti* necesitan ser movilizados urgentemente a través de diversos canales de comunicación por parte del gobierno, alcanzando a las familias, con prioridad a aquellas ubicadas en zonas de alto riesgo, especialmente las regiones recientemente inundadas.
Palabras clave: Arbovirus; Virus del Dengue; Inundación; Cambio climático.

1. Introduction

Climate change occurring worldwide is among the most significant global challenges. Various environmental factors have contributed to episodes of different weather phenomena (Bhatia et al., 2022). Among these, the most notable can be evidenced by floods around the world (Coalson et al., 2021).

As in other parts of the world, Brazil has faced unprecedented flooding throughout its territory. As highlighted by Mantovani et al. (2021), floods in Brazil are particularly concerning since the climatic phenomena El Niño and La Niña play a crucial role in increasing flood risks in various regions of the country. Additionally, the accelerated reduction of forests plays an important role in regulating humidity and rainfall (Oliveira et al., 2023). Thus, excessive rainfall raises greater concern in the most productive areas, near large rivers, where disasters can be more severe.

The international press recently reported floods in the southern part of the country, specifically in the state of Rio Grande do Sul (RS), during the month of May. This state has a temperate climate with hot summers and a small area in the northeast region, situated at higher altitudes, that experiences mild summers and cold winter, and sometimes snow falls. The annual average temperature varies between 14°C and 22°C (IBGE, 2024). The state has a territorial extension of 281,730.2 km², occupying more than 3% of Brazilian territory. Divided into 497 municipalities (Fig. 1), it has 11.3 million inhabitants, corresponding to 6% of the national population. The capital, Porto Alegre, is the most populous municipality with 1.4 million inhabitants (IBGE, 2024).

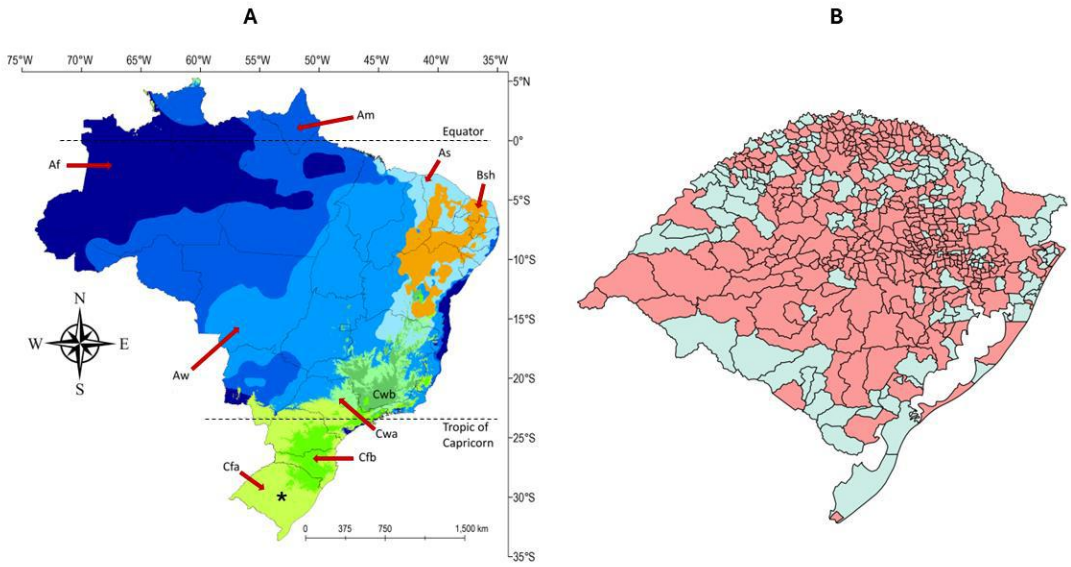
2. Methodology

A bibliographic and documentary survey was conducted by the authors, including reports from the Ministry of Health, the Unified Health System, and data from the Municipal Government of Porto Alegre, regarding the number of cases of Dengue. An analysis of data from the National Institute of Meteorology was also performed, using historical annual precipitation data for the specified period. Relevant literature on the subject was consulted to highlight the essential points for the ideal composition of this work (Pereira et al., 2018).

3. Results and Discussion

It is important to note that RS has one of the most water-abundant hydrographic networks in Brazil, with a dense surface hydrographic network, divided into three major basins: Uruguay Basin, which drains about 57% of the total area of Rio Grande do Sul; Guaíba Basin, 30%; and the Coastal Basin, covering about 13% of the territory. It also has large reserves of groundwater, among them the Guarani Aquifer, one of the largest groundwater reserves in the world, encompassing about 18% of its total area in RS (FEE, 2024).

Figure 1 - Partial map of South America, Brazil, and the State of Rio Grande do Sul; A) Territorial division of Brazil with Köppen-Giger climate criteria.



humid temperate with hot summer (Cfa);

humid temperate with temperate summer (Cfb); B) Area of the State of Rio Grande do Sul affected or not by the floods of May 2024; municipalities directly affected by the floods (in salmon); municipalities not affected by the floods (in light green).

Source: Adapted from Alvares et al. (2013); State of Rio Grande do Sul climat.e

The recent floods caused significant economic losses for RS, affecting the agriculture, industry, and commerce sectors, and displacing thousands of people who lost their homes due to the floods. A total of 540,188 families were displaced (Defesa Civil, 2024), as 471 of the 497 cities in the state were affected by the storms-equivalent to 94.77% of the total. Thus, only 26 were unaffected by the rains.

In addition to economic losses, floods can lead to various infectious diseases as a direct consequence of contact with water, such as diarrheal diseases (Wang et al., 2023) and leptospirosis (Bradley et al., 2023; Martins-Filho et al., 2024). Floods also provide new breeding grounds for mosquitoes, consequently increasing cases of malaria and arboviral diseases (Coalson et al., 2021; Liu et al., 2023). Currently, Dengue is one of the most concerning arboviral diseases globally, and Brazil has been responsible for a significant number of cases nationwide. This is likely due to a reduction in informational campaigns directed at the entire population by federal, state, and municipal governments. Additionally, climate change has produced environmental modifications, facilitating an increase in the mosquito population, especially *Aedes aegypti*, which is responsible for transmitting all four dengue serotypes in South America, particularly in Brazil.

According to the Brazilian Ministry of Health (2024) throughout 2023, 1,649,144 cases of Dengue were reported, with 1,179 deaths. Comparatively, in 2024, the number of reports reached 6,148,161 with 4,207 deaths by the 25rd week, i.e., by early June. In this context, the State of Rio Grande do Sul has a 12.66% fatality rate for severe cases, the second highest in the country.

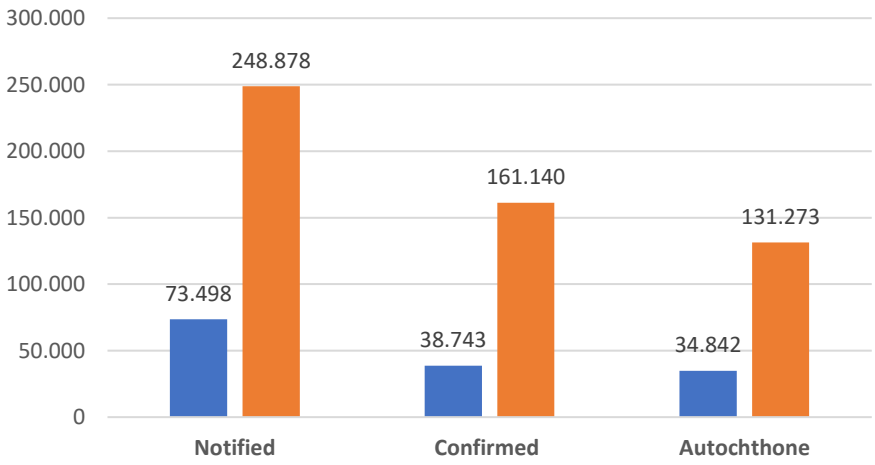
During this flood period, the population of Rio Grande do Sul is in autumn, a season when temperatures should disfavor mosquito activity. As mentioned, this region of Brazil is known for its warm temperate climate, which would control mosquito proliferation in the colder months. However, due to climate change, the region has experienced milder winters with temperature peaks equivalent to spring or summer, even in the winter season. These changes in RS corroborate studies (Nuñez et al., 2009; Alves et al., 2020; Kreibich et al., 2022) that demonstrate a future climate evolution where moisture concentration, with the possibility of floods, will contrast with periods of drought.

The Brazilian government has been aware of these possibilities since 2016, when the "Brazil 2040" project was presented, and its full text was recovered (Dias, 2015). This study was commissioned to scientifically assess the possible impacts of climate change in Brazil by 2040 and propose measures to mitigate them. Unfortunately, environmental safeguards based on this project are still insufficient. Consequently, preservation and environmental repair measures are inadequate, resulting in long periods of drought and poorly distributed rains, causing floods. Evidently, this contributes to the increased risk of diseases like Dengue, whose incidence increased by 54% from 1951-1960 to 2013-2022 in Latin America (Hartinger et al., 2024).

To further aggravate the situation, the Dengue in RS was already considered epidemic in April 2024, with 838.9 cases per 100,000 inhabitants and 73 confirmed deaths, according to the State Health Department's Epidemiological Surveillance Division (2024).

According to the State of Health Department of Rio Grande do Sul (2024) by June 2024, the state had 169,969 confirmed cases of Dengue, representing a 315.9% increasing comparing to 2023. Among this number, 131,273 were considered autochthonous (Figure 2). Regarding the number of deaths, by June 2024, the state confirmed 266 deaths, 357.4% more than all the reported cases in 2023 with 54 deaths.

Figure 2 - Comparison of reported Dengue cases in Rio Grande do Sul from 2023 to 2024.
Years: blue column (2023); orange column (2024).



Source: SES/RS.

In light of these facts, the main concern lies in the possibility of a significant increase in *Ae. aegypti* and other vector breeding sites in this region of Brazil. This increase is due to the presence of standing water in various locations, either from the

formation of new flood areas resulting from modifications in riverbeds in the affected urban areas or from the proliferation of artificial breeding sites from the debris of destroyed homes, commercial, and industrial establishments, as well as animal farms. *Aedes aegypti* eggs survive in dry environments, acquiring desiccation tolerance at a late development stage stage (Prasad et al., 2023; Dilly et al., 2023). This implies that eggs in a period of desiccation tolerance could have been encountered by the water in the currently flooded areas, which were previously not in contact with water (Prasad et al., 2023).

Simões et al. (2013) conducted a study in Brazil indicating that the mosquito population tends to increase when temperatures are above 23°C and relative humidity exceeds 54%. The wavelet analysis conducted by the authors identified non-stationary local effects of meteorological variables on mosquito abundance over the study period, with peaks occurring during spring and summer. These data reiterate the possibility of increased mosquito development throughout RS, as maximum temperatures during spring rise on average by 7°C, ranging from 19°C to 22°C, rarely going below 16°C or above 33°C (WheaterSpark, 2024).

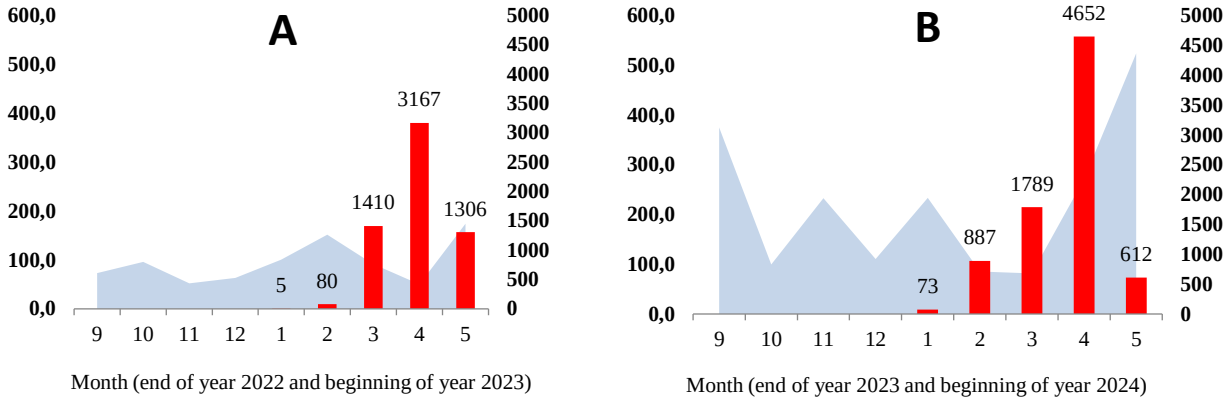
In Brazil, literature confirms the correlation between hot and rainy seasons and the increased incidence of Dengue (Viana & Ignotti, 2013; Duarte et al., 2019; Xavier et al., 2021; Machado et al., 2023). More recently, it was verified that climate changes, with the increase in the number of hotter days in summer, have a significant relationship with the expansion of Dengue in Brazil (Barcellos et al., 2024). However, studies documenting the impact of floods on Dengue incidence in affected areas are scarce (Anyamba et al., 2019; Coalson et al., 2021).

It should be considered that, in the case of floods in RS, there is a stark contrast between the use of technically adequate measures for reoccupying devastated areas and the technically simplistic measures proposed by politicians and laypeople (Malabarba et al., 2024). To solve a social emergency, these measures become permanent and sensitive to new calamities. The mobilization to overcome the floods in RS must address both immediate sanitary needs and long-term recovery and prevention, requiring the collaboration of all society segments to avoid cascading health crises (Martins-Filho et al., 2024).

The collaborative effort for recovery can and should involve the press in unifying specific campaigns and actions (Moller, 2024; Nauta, 2024). However, the local press has so far issued brief alerts about necessary precautions regarding venomous animals that may have moved from their original habitats to urban environments. There have also been recommendations for vaccination against flu (Influenza) and other respiratory diseases, as well as the risk of leptospirosis. However, regarding Dengue and other arboviral diseases, there has been no communication on the same scale and with equal access to information for the society at large.

The need to resize alerts to the general population becomes even more pressing, considering indications that the city of Porto Alegre is subject to higher Dengue infection rates. Despite the scarcity of studies linking post-flood periods to Dengue outbreaks and the lack of correlation between climate, incidence, and periodicity of Dengue as pointed out by Breda and Motta (2024), these associations cannot be ruled out. The data presented in Figure 3 indicate that in Porto Alegre there was an increase in confirmed dengue cases in 2024 compared to the same period in 2023, which could possibly be related to the increase in precipitation levels in the months preceding the epidemic.

Figure 3 - Comparison between precipitation (mm/month; blue area) and dengue-related deaths (red column) in Porto Alegre, during 8 months both in 2023 (A) and 2024 (B).



Source: Adapted from SES/RS (2024) and INMET (2024).

We highlight that it is possible to observe in Figure 3, as in the studies by Coalson et al. (2021), Liu et al. (2023), Shaikh et al. (2023) and Silva et al. (2021), a significant increase in Dengue cases following periods of flooding in conducive climates, which may indicate favorable conditions for the development of the *Aedes aegypti* mosquito after prolonged and consistent periods of rain.

4. Conclusion

Prevention campaigns and efforts to combat the spread of the *Ae. aegypti* mosquito urgently need to be mobilized through various communication channels by the government, reaching households, ensuring that information reaches all households. Priority should be given to the population located in high-risk areas, especially those recently affected by flooding, where conditions favorable for mosquito breeding are more evident. Furthermore, is crucial for health systems to prepare for proper screening and continuous monitoring of potential patients affected by arboviral diseases, such as Dengue, which tend to increase as a result of the floods.

Given the scarcity of research on the correlation between floods and the increase in dengue cases, it would be beneficial to carry out studies in different regions of the country, in order to identify and quantify this relationship more precisely.

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Conflict of Interest

The authors declare no competing interests.

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