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CLIMATE CHANGE AND NEGLECTED DISEASES: THE DENGUE EPIDEMY IN SOUTHERN BRAZIL

Mudanças climáticas e doenças negligenciadas: a epidemia de Dengue na Região Sul do Brasil

Cambio climático y enfermidades desatendidas: la epidemia de dengue em el sur de Brasil

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Abstract: Dengue, a significant neglected disease, is experiencing rapid escalation and geographic expansion, particularly in the context of climate change. As a multifactorial disease, it is associated with various determinants, with climate serving as the primary factor driving the proliferation of the Aedes aegypti vector. However, it is also linked to socio-environmental elements and public policies. In this regard, global warming plays a critical role in the increase of dengue epidemics due to its direct influence on the ecology of the disease vector. This study examines the intersection of dengue proliferation and climate change in Southern Brazil, a region historically less affected by the disease due to its cooler climate. The investigation utilized databases from the Brazilian Ministry of Health (DataSUS) and meteorological data provided by the National Institute of Meteorology (INMET). In 2023 and early 2024, Brazil reported an unprecedented number of dengue cases—3,000 per 100,000 inhabitants, totaling over 6 million cases by July 2024—coinciding with record-breaking temperatures. Furthermore, a positive trend in dengue cases and rising temperatures was identified in southern Brazil between 2007 and 2024. Additionally, we critique current public health policies in Brazil, particularly the limitations of a mosquito-centered control approach. We propose more comprehensive strategies that address the socio-environmental vulnerabilities exacerbated by climate change, aiming for integrated public health responses that consider the biological and social determinants of dengue amid ongoing climate emergencies.

Keywords: Climate change. Dengue. Public health policy. Aedes aegypti. Socio-environmental vulnerability.

Resumo: A dengue, uma doença negligenciada significativa, está passando por uma rápida escalada e expansão geográfica, particularmente no contexto das mudanças climáticas. O aquecimento global desempenha um papel crítico no aumento das epidemias de dengue devido à sua influência direta na ecologia do *Aedes aegypti*, principal vetor da doença. Em 2023 e no início de 2024, o Brasil registrou um número sem precedentes de casos de dengue — 3.000 por 100 mil habitantes, totalizando mais de 6 milhões de casos até julho de 2024 — coincidindo com temperaturas recordes. Este estudo examina a interseção entre a proliferação da dengue e as mudanças climáticas na Região Sul do Brasil, uma área historicamente menos afetada pela doença devido ao seu clima mais ameno. Por meio da análise de dados epidemiológicos e fatores climáticos, o artigo explora como o aumento das temperaturas e as alterações nos padrões de chuva criaram condições favoráveis à disseminação da dengue. Além disso, criticamos as atuais políticas de saúde pública no Brasil, particularmente as limitações de uma abordagem centrada no mosquito, e sugerimos estratégias mais abrangentes que abordem as vulnerabilidades socioambientais agravadas pelas mudanças climáticas. Este trabalho destaca a necessidade urgente de respostas integradas de saúde pública que considerem tanto os determinantes biológicos quanto os sociais da dengue diante das emergências climáticas em curso.

Palavras-chave: Mudança climática. Dengue. Saúde pública. Aedes aegypti. Vulnerabilidade socioambiental.

Resumen: El dengue, una enfermedad desatendida significativa, está atravesando una rápida escalada y expansión geográfica, particularmente en el contexto del cambio climático. El calentamiento global desempeña un papel crítico en el aumento de las epidemias de dengue debido a su influencia directa en la ecología del *Aedes aegypti*, principal vector de la enfermedad. En 2023 y a inicios de 2024, Brasil registró un número sin precedentes de casos de dengue — 3.000 por cada 100 mil habitantes, totalizando más de 6 millones de casos hasta julio de 2024 — coincidiendo con temperaturas récord. Este estudio examina la intersección entre la proliferación del dengue y el cambio climático en la Región Sur de Brasil, un área históricamente menos afectada por la enfermedad debido a su clima más templado. A través del análisis de datos epidemiológicos y factores climáticos, el artículo explora cómo el aumento de las temperaturas y las alteraciones en los patrones de lluvia han creado condiciones favorables para la diseminación del dengue. Además, criticamos las políticas actuales de salud pública en Brasil, particularmente las limitaciones de un enfoque centrado en el mosquito, y sugerimos estrategias más integrales que aborden las vulnerabilidades socioambientales agravadas por el cambio climático. Este trabajo resalta la necesidad urgente de respuestas integradas de salud pública que consideren tanto los determinantes biológicos como los sociales del dengue frente a las emergencias climáticas en curso.

Palabras clave: Cambio climático. Dengue. Salud publica. Aedes aegypti. Vulnerabilidad socioambiental.

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1. INTRODUCTION

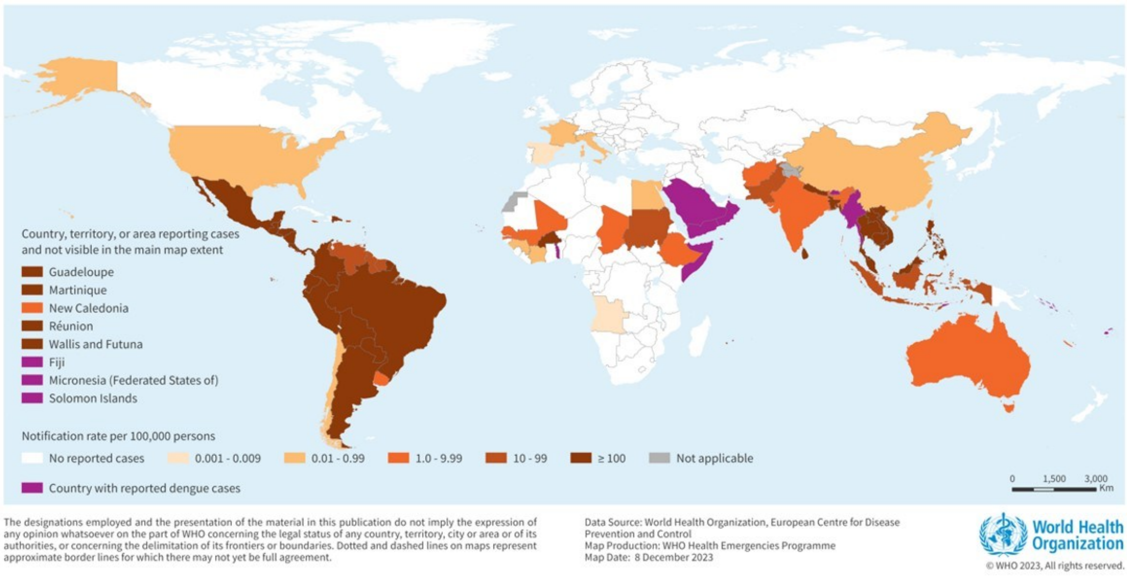
Many human diseases thrive in the face of global climate changes; the climate emergency is acting as a strong catalyst for various already known diseases and it is estimated that it could lead to new problems for human health. Among those diseases are Neglected Diseases (WHO, 2024), also known as diseases of poverty or of the Global South.

Present and future scenarios of accelerating global climate warming, which result in changes in rainfall and air movement around the world, point to the aggravation of many problems related to the well-being and health of populations. This has raised concerns about the development and implementation of measures to deal with epidemic and pandemic situations as there is an increased risk of the spread and intensification of diseases common to humid tropical areas, such as dengue.

In the first semester of 2024, dengue cases reached the highest number ever recorded, with more than 10 million cases in Latin America and the Caribbean alone. During the same period in Brazil, the epidemic reached alarming levels (over 6 million cases, an incidence of 3,033 cases per 100,000 inhabitants), a situation which, coupled with very high temperatures (the hottest year since 1850), has put public health and the entire population on alert. In the last year and a half, dengue has been detected practically all over the country, with significant spatial variation but with very high rates across the country.

The study of the Dengue Complex (Mendonça, 2021) demands a multi-causal approach: it is necessary to analyze elements from not only the natural environment (climate), but also the built environment (urbanization, environmental sanitation, etc.) and the social environment (way of life, public policies, etc.). Historically confined to the average isotherms of 10ºS/N until the second half of the 20th century, dengue has greatly expanded its geographical range to higher latitudes and altitudes (Figure 1) in the context of global climate change.

Figure 1. Countries/territories/areas reporting autochthonous dengue cases (November/2022 to November/2023)



Note: Based on the most recent available data (data should be interpreted bearing in mind differences in reporting rates and case definitions between regions).

In this context, the first part of this study introduces the concept of neglected diseases, followed by a brief look at the spread of dengue in Brazil in the light of global climate change. In the third part, the text deals with the spread of dengue in the southern region of Brazil – a region which, especially due to its climatic conditions, has been mostly unaffected by the disease for around three decades since its reintroduction in the country. The last part of the text critically analyzes Brazil's public policies to deal with the disease. Much of the analysis highlights the risks and vulnerabilities associated with the intensification and spread of dengue in the context of present and future climate change and climate emergency.

2. MATERIALS AND METHODS

Disease data were collected through Datasus – the Department of Informatics of the Unified Health System (DATASUS, 2024) – covering the period from 2001 to 2024 (up to March 2024). Data from municipalities in the southern region of Brazil were processed with monthly values, as this is the temporal format available online and accessible to researchers. For calculating disease incidence, population values from the 2000, 2010, and 2022 censuses (IBGE, 2024) were used, all adjusted to a base of 100,000 inhabitants.

Climatic data were obtained annually and provided by the National Institute of Meteorology (INMET, 2024). These data were processed daily and averaged into monthly values.

3. NEGLECTED DISEASES (OR DISEASES OF POVERTY): INCREASED IMPACT IN THE CONTEXT OF GLOBAL CLIMATE CHANGE

Neglected Diseases (NDs) have emerged as a global health concern, with the concept coined in the 1970s by Kenneth S. Warren, who highlighted the lack of investment in research for illnesses such as malaria and schistosomiasis (Molyneux et al., 2021). In 2001, Médecins Sans Frontières (MSF) defined NDs as disabling or lethal diseases with insufficient government and market responses, characterizing political and economic failures (MSF, 2001). That same year, the World Health Organization (WHO) classified them into three types: Type I (present in both rich and poor countries); Type II (more prevalent in poor countries); and Type III (virtually restricted to developing nations), with the latter two categorized as neglected and highly neglected diseases, respectively (WHO, 2001).

The WHO later systematized the characteristics of Neglected Tropical Diseases (NTDs), including: (a) severe socioeconomic impact; (b) higher incidence in marginalized populations; (c) limited geographic coverage; (d) stigmatizing and discriminatory potential, especially against women; (e) significant morbidity and mortality; (f) lack of scientific research; and (g) the possibility of control through strategic interventions (WHO, 2007; 2010). However, the term "tropical" is criticized by Gondim de Oliveira (2018, p. 2297), who associates it with colonial spaces, reinforcing geopolitical and cultural demarcations, as well as historical inequalities.

These definitions demonstrate how NDs reflect structural failures of the global system, with higher prevalence in the Global South, exposing disparities in health and access to scientific knowledge. The production of knowledge about neglected diseases (NDs) reflects market, scientific, and political failures (MSF, 2001; Morel, 2006; Molyneux et al., 2021), with direct implications for the living conditions of vulnerable populations. These inequalities are intrinsically linked to the Social Determinants of Health (SDH), which highlight the relationship between climate change and the increase in NDs. Buss and Filho (2007, p. 78) emphasize that living and working conditions impact health, although this relationship is not linear (p. 81). Laurell (1982) argues that reducing the health-disease process to biological factors is limited, as even human biology is socially determined by historicity.

This perspective was incorporated into the Declaration of Alma-Ata (1978) and the creation of the Commission on SDH by the WHO (2005). Gondim de Oliveira (2018, p. 2300) summarizes: "They are neglected diseases because they belong to neglected people," as evidenced in Brazil, where 54.2% of deaths from NDs (2000-2019) occurred among Black or mixed-race individuals, and 89.3% among those with seven or fewer years of schooling (Rocha et al., 2023, p. 3). The IPCC (2023) warns that climate change exacerbates food and water insecurity, increasing the incidence of vector-borne, waterborne, and foodborne diseases, while also widening socioeconomic and gender inequalities. Lankes et al. (2022) highlight that poverty intensifies vulnerability to health crises, disasters, and conflicts, aggravated by climate. Thus, NDs reveal not only a public health challenge but a structural problem linked to social and environmental injustices.

Studies show that global climate change directly affects disease transmission and incidence. Mendonça (2003; 2021) and Queiroz et al. (2020) emphasize that variations in global average temperature influence infection conditions, accelerating vector life cycles and pathogen transmission. Mora et al. (2022) identified 3,213 empirical cases in which 277 of 286 diseases were aggravated by climate hazards. Climate projections for future scenarios, such as those by Mendonça et al. (2003; 2021) and Soek et al. (2022), show the influence of meteorological variables (temperature and precipitation) on the prevalence of dengue and other diseases due to the impact on the behavior of the Aedes aegypti vector. This relationship is critical, as dengue's seasonality (Banu et al., 2016, p. 243) is being altered by reduced seasonal differences and increased heat waves. Luna (2002, p. 235) also highlights the link between climate change and reemerging diseases, such as cholera and leptospirosis, aggravated by droughts and floods.

Preventing climate-related health emergencies faces obstacles, such as insufficient training for Primary Health Care (PHC) workers, including Community Health Workers (CHWs) and Endemic Disease Control Agents (EDCAs), in symptoms, diagnosis, and surveillance (Garcia et al., 2022). Rocha et al. (2023) criticize the lack of government prioritization of neglected diseases (NDs), advocating for expanded diagnostic testing and the integration of patients into PHC to reduce vulnerabilities. Diniz et al. (2021) warn of the risk of COVID-19 becoming an ND, emphasizing the need for public policies based on solidarity, combating inequities, and ensuring social protection. Soares et al. (2023) reinforce that reducing inequalities and poverty is the most effective strategy to mitigate the impacts of NDs.

Health, a fundamental right, must be a priority in public policies. Oliveira et al. (2019, p. 11) state: "We all have the right to the highest attainable standard of physical and mental health, without discrimination." In Brazil, Law 8.080/1990 establishes health as a duty of the state, requiring economic and social policies that reduce risks and ensure universal access (Brazil, 1990).

NDs are intrinsically linked to poverty and failures of the market, governments, and science. Addressing them requires recognizing these gaps and implementing actions that combat inequalities, ensuring dignity and preventing avoidable deaths. In the face of climate change, which intensifies these diseases, it is urgent to integrate public health strategies, social justice, and sustainability.

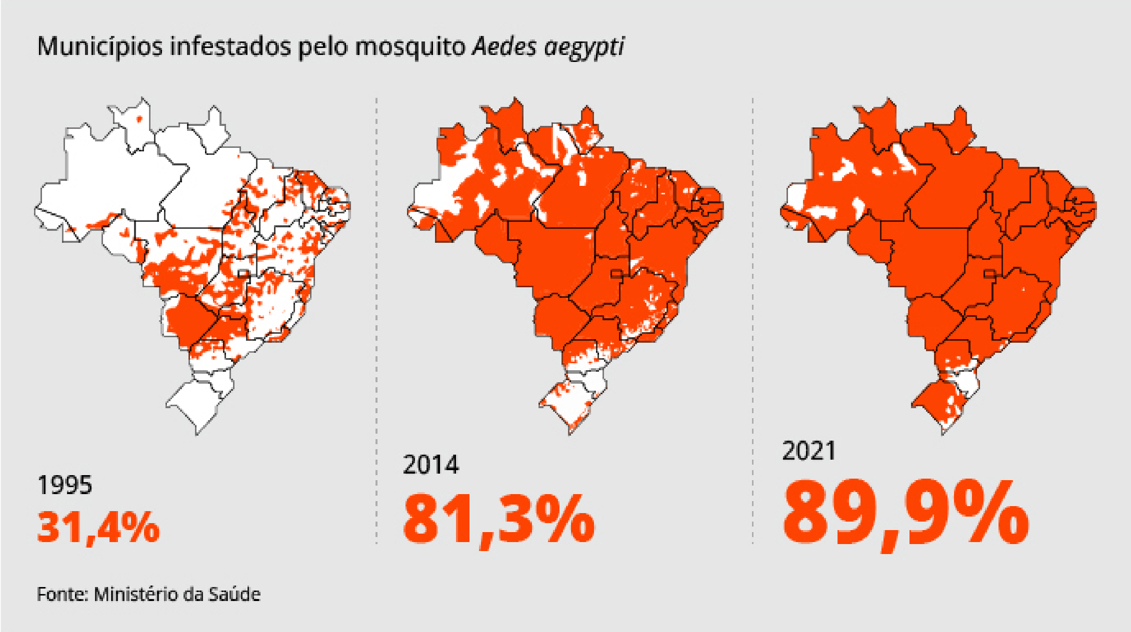
4. DENGUE IN BRAZIL: A CONVERGENCE OF SOCIAL INJUSTICE AND GLOBAL WARMING

The first 17 weeks of 2024 have highlighted dengue as a critical public health emergency in Brazil, with 6,159,160 probable cases and 4,250 deaths—an unprecedented incidence rate of 3,033 cases per 100,000 inhabitants (as of 01/07/2024). This surge reflects a global trend: PAHO (2024) reports cases in the Americas rose from 1.5 million in the 1980s to 16.2 million (2010–2019), with 2023–2024 infections 225% higher than the previous five-year average. Approximately 500 million people in the Americas are at risk.

Dengue's prevalence in Latin America and Africa stems from environmental susceptibility and urban inequality (Barata, 2009). WHO (2009) notes a 30-fold global incidence increase over 50 years, with 390 million annual infections (96 million symptomatic; Bhatt et al., 2013). Recent autochthonous cases in the U.S. and Europe (ECDC, 2023) underscore its expanding range, driven by climate change, urbanization, and ineffective vector control (Gould et al., 2017).

In Brazil, Aedes aegypti infestation grew from 31.4% of municipalities in 1995 to 89.9% (2014–2021), fueled by urbanization and climate shifts (Gregianini et al., 2017). The crisis demands integrated strategies addressing social inequalities, climate adaptation, and public health infrastructure to curb its global spread.

Figure 2: Infestation of *Aedes aegypti* in Brazilian municipalities – 1995, 2014 and 2021.



Source: Ministério da Saúde (2024)

The perspective of pathogenic complexes from a geographical approach (Sorre, 1951) reveals the interaction between the natural, biological and social environments, allowing for a multi-causal analysis of the health-disease process in populations through the lens of its spatial expression. Thus, the spread of dengue depicted in Figure 2 matches the evolution and complexification of the Brazilian urban network, revealing the social determinants of the logic of epidemics, outbreaks and endemics, whose explanation also lies in the unequal and corporative urbanization that has unfolded in Brazil (Santos, 1993). This can be seen in the unequal access to basic sanitation throughout the country, especially in the North, Northeast and Center-West regions where, according to the IBGE's Atlas of Basic Sanitation (2021), people have the lowest percentage of access to piped water and sewage treatment in the country. Not coincidentally, these regions have also reported historical increases in dengue cases.

Another aspect of Brazil's urbanization process is the intense altering of environmental factors, especially climatic variables, which provide suitable conditions for the proliferation of the vector (Gregianini et al., 2017). Climate has a decisive role in the development of dengue fever, one of the main arboviruses and the subject of several studies (Oscar Júnior; Mendonça, 2021; Oliveira, 2019; Aleixo: 2011; Mendonça et al., 2011; Hayden, 2010; Consoli, 1994). *Aedes aegypti* is usually found in humid tropical and subtropical regions between latitudes 35° N and 35° S. They can also be found outside these limits, but very close to the average annual isotherm of 20°C or the winter isotherms of 10°C, evidencing that the climate is an endemic condition for the mosquito (Consoli, 1994).

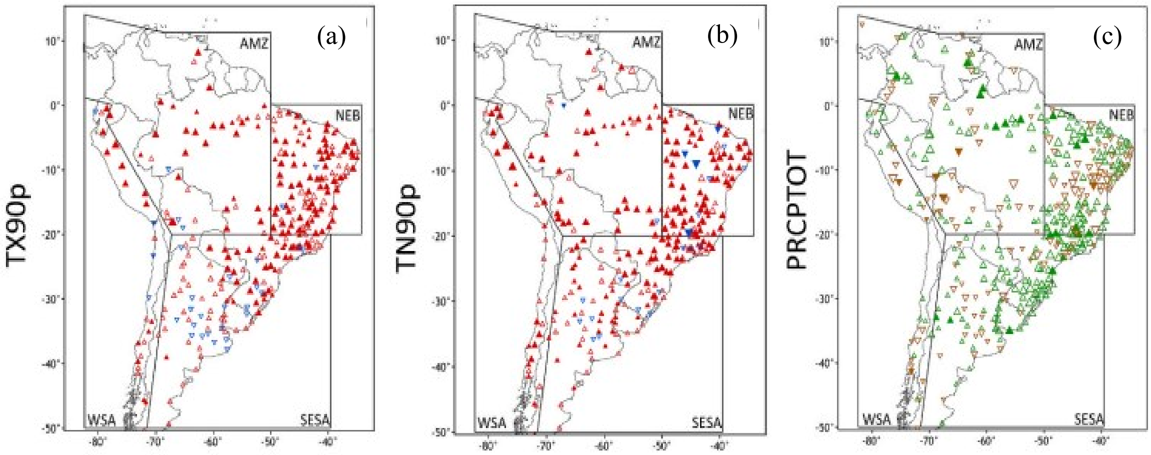
It is relatively well established in scientific research that the climatic conditions that most influence living beings in the process of arbovirus transmission are air temperature, relative humidity and rainfall, although there is also a small interference of wind speed in the movement of the vector (Rouquayrol, 1999).

Temperature and rainfall affect the vector population and can influence dengue transmission. The abundance of *Aedes aegypti* is partially regulated by rainfall, creating breeding sites and stimulating the development of eggs (Foo et al., 1985). Temperature, on the other hand, influences the mosquito's ability to survive and determines its development and reproductive rates (Johansson, 2009; Mendonça et al, 2011).

Mendonça (2003), Reiter (2004), Patz et al (2005) and Confalonieri and Marinho (2007), among many others, have established important links between global climate change and human health. In their analysis, they have highlighted the prospects of global climate warming and its repercussions on health, stressing that changes in the distribution and intensity of rainfall, temperatures and air humidity in Brazil have direct implications for the ecology and population dynamics of the mosquito.

A study by Dereczynski et al. (2020) analyzed indicators of climate change and extremes for the whole of South America based on observational data from 1969 to 2009. As shown in Figure 3, adapted from the authors, the indices of TX90p - hot days (a) and TN90p - hot nights (b) showed the prevalence of trends related to hot extremes in a significant part of the country. The results corroborate those of Dunn et al. (2020) who argue that, given the global warming trend, the number of cold days and nights (TX10p, TN10p) will decrease, offering optimal conditions (high susceptibility) for the proliferation of the dengue-transmitting mosquito in areas where they were previously not found, such as mountainous areas (Oscar-Júnior; Mendonça, 2021) and the southern region of Brazil (Mendonça et al., 2019).

Figure 3: South America - Climate change based on observational data (1969-2009) for (a) TX90p - hot days, (b) TN90p - hot nights and (c) PRCPTOT - annual number of rainy days in mm.



Source: Adapted from Dereczynski et al. (2020).

The red triangles indicate an increase in the number of hot days and nights, while the blue triangles indicate their decrease. The green triangles indicate an increase in the annual number of rainy days in mm, while the brown triangles indicate their decrease.

Another index studied by Dereczynski et al. (2020) was the PRCPTOT - annual number of rainy days (c), as seen in Figure 2, which shows a trend towards an increase in rainy days in Brazil – another key factor in the mosquito's life cycle. The thermo-pluviometric trends contribute to the geographical expansion of dengue across the country, increasing the numbers of people exposed to infection. As such, Figure 2 and Figure 3 show the intersection between the spread of *Aedes Aegypti* infestation in Brazil and areas with increased numbers of hot days and nights and rainy days.

Barcellos et al. (2024) have also shown that urbanization and the incidence of temperature anomalies over a prolonged period are the main factors that have led to an increased number of cases of dengue in Brazil. Furthermore, Oscar Júnior and Mendonça (2021) point out that high-altitude regions, which previously acted as a barrier to dengue transmission, now have high rates of the disease, unveiling new spatial and seasonal logics.

According to Evans (2019), it is important to recognize that climate change will also influence human behavior, leading to changes in patterns of exposure to mosquitoes and in the search for medical treatment. This could further contribute to the spread of the disease, especially among those who have limited access to resources to deal with it (such as air conditioning, control of breeding sites, access to medical and hospital infrastructure, etc.), reinforcing its status as a neglected disease, i.e., a disease of poverty.

5. THE SPREAD OF DENGUE IN SOUTHERN BRAZIL: EVIDENCE OF ITS ESCALATION IN THE CONTEXT OF GLOBAL CLIMATE CHANGE

The spread of dengue to the southern region of Brazil has been constrained mainly by climatic conditions, as its vector does not thrive at temperatures far from the limits of its climatic optimum. The ideal limit for the vector's larval development is between 22ºC and 32ºC until the adult stage (Beserra et. al., 2009), in addition to the need for intermittent rainfall for the formation of breeding sites.

Until the early 2000s, only the state of Paraná had recorded significant cases of dengue in Southern Brazil; in 2003, for instance, 97.4% of reported cases were in this state. Oliveira (2006), when relating dengue cases and vector infestation rates to the climatic characteristics of Paraná, identified its predominance in the warmer areas of the state.

Looking at the temporal behavior of confirmed cases and the disease's incidence, it is clear that until 2014 it was mostly concentrated in the state of Paraná. There were records in the state of Rio Grande do Sul (Colhishon et al, 2018), but they were isolated and located in the northwest of the state (Table 1).

Table 1: Southern region states: dengue cases and incidence - 2007-2024

Paraná	**Year**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
	Cases	25884	1039	950	34436	29089	3685	59833	20021	42360
	Inc*.	225.66	9.06	8.28	300.19	253.58	32.12	521.59	174.53	369.27
	Year	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
	Cases	57919	879	837	41075	237284	27243	145925	165012	157238
	Inc*.	504.90	7.66	7.30	358.07	2068.50	237.49	1271.98	1438.36	1370.59
Santa Catarina	**Year**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
	Cases	113	55	46	166	131	79	284	72	3679
	Inc*.	2.11	1.03	0.86	2.66	2.10	1.26	4.55	1.15	58.91
	Year	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
	Cases	4451	24	64	1952	11443	19166	83388	119160	30162
	Inc*.	71.27	0.38	1.02	31.25	183.22	306.88	1098.59	1569.87	397.37
Rio Grande do Sul	**Year**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
	Cases	3477	3231	3240	3319	217	994	2240	2144	2143
	Inc*.	22.59	20.99	21.05	31.53	2.06	9.44	21.28	20.37	20.36
	Year	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
	Cases	1661	1858	6496	47652	66157	81420	67206	38223	37956
	Inc*.	15.78	17.65	61.71	452.64	628.42	773.41	1252.07	712.11	707.13

*Incidence per 100,000 inhabitants.

Source: MS (2024).

Mendonça (2003) and Oliveira (2006) reported the presence of the vector and dengue cases in regions classified by Köppen as Cfa (temperate climate with hot summers, no dry season, and an average temperature in the hottest month above 22ºC). In the south and southeast of Paraná, where the climate type is Cfb (temperate climate with cool summers, no dry season, and an average temperature in the hottest month below 22ºC), there were only isolated cases in some municipalities.

In the state of Paraná, major dengue epidemics took place in 2007, 2009-2010, 2013, 2015, 2020 and 2022 to 2024 (ongoing), as shown in Table 1. However, in 2015 the state of Santa Catarina recorded an all-time high, rising from 72 cases in 2014 to 3679 in 2015; the highest number of cases in Santa Catarina were recorded between 2022 and 2023. The same did not happen in Rio Grande do Sul, which had already been reporting around 2,000 cases a year since 2013; in 2021 it had the highest number of cases within this period, totaling 8,120 cases.

The incidence rates differed between the three states, with higher rates being recorded in different periods due to, among other reasons, the characteristics of viral circulation and pre-existing vulnerabilities. In Paraná, the highest incidence rate was recorded in 2020, Santa Catarina in 2021, and Rio Grande Sul in 2022.

The first quarter of 2024 has confirmed the magnitude of the dengue epidemics ravaging the whole country, with 2,321,050 probable cases as of March, with an incidence of 1,143 per 100,000 inhabitants and 831 confirmed deaths (COE/MS, 2024).

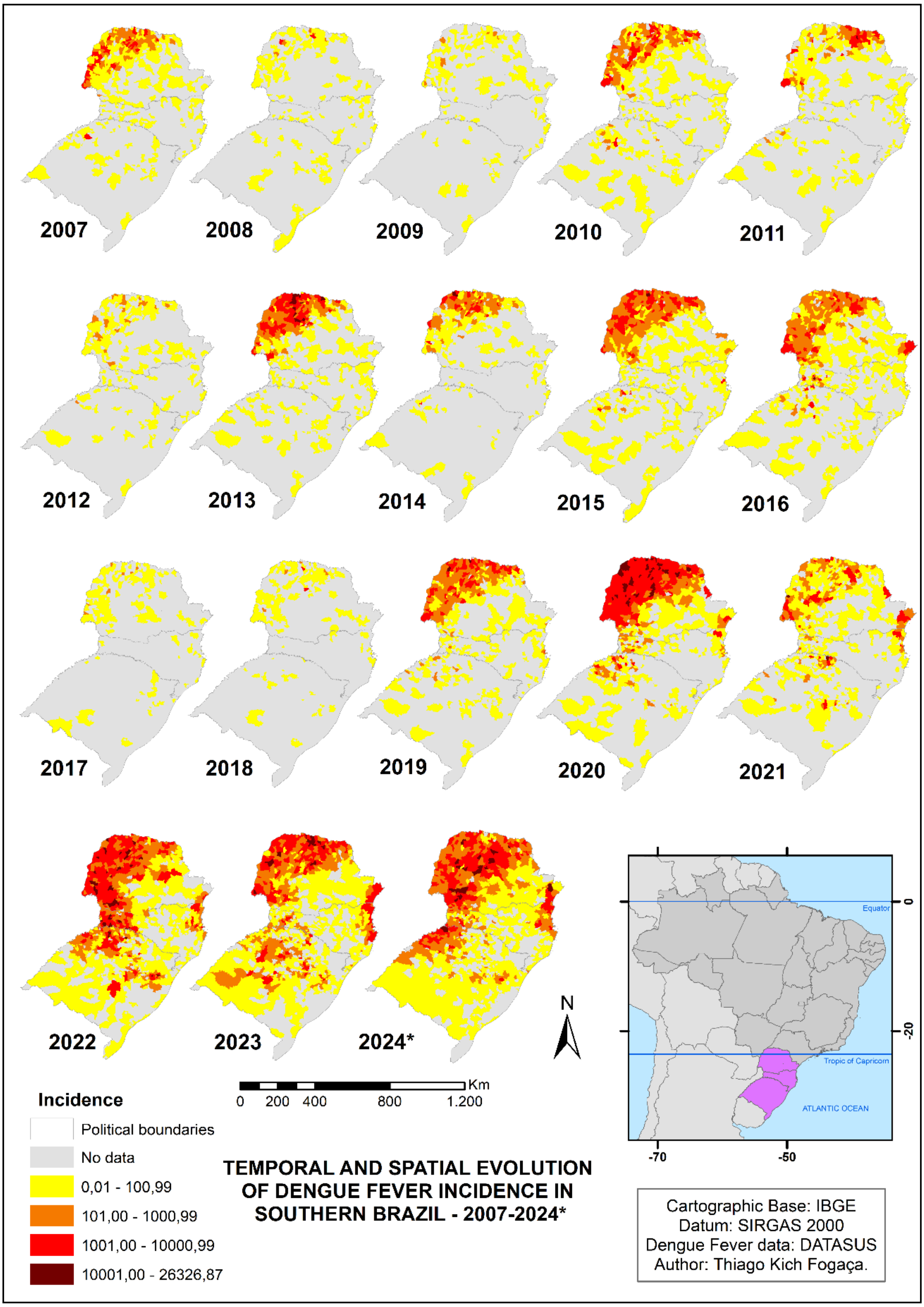
Climate influence as pointed out by Mendonça (2003) and Oliveira (2006) is illustrated in the mapping of the disease's incidence between 2007 and 2024 (Figure 4), with better evidence up to 2014, especially in the Cfa climate regions of the state of Paraná, which have the highest incidence throughout the period.

Since 2007, cases of the disease have been recorded in the southernmost municipalities of Brazil, but they have been less severe, i.e., the population has been less infected in these areas. However, the disease has spread after 2015, especially in the current year and in 2016 and 2019.

Much of the northwest and west of the state of Paraná recorded an incidence of over 1000 cases per 100,000 inhabitants from 2020 onwards. It is also evident that the virus circulated more widely in the south of Rio Grande do Sul after 2022, although the highest incidences were in the central region of the state. The central region of the state of Santa Catarina is characterized by terrain with altitudes of over 900 meters, and over 1,200 in certain locations; due to the orographic effect, these locations have low temperatures compared to other climates in Brazil, and therefore have no or fewer cases of the disease. On the other hand, in the lower areas of the state, the highest incidences are concentrated in the far east and west, where the altitude is lower than 600 meters and the temperatures favor the vector's development.

The conditioning factors of dengue include environmental, social, economic and cultural issues, as mentioned earlier, and require an in-depth analysis of all these factors. However, for the purposes of this article, we have focused on climate and viral circulation (DENV1, DENV2, DENV3 and DENV4), the latter due to the process of seroprevalence and the consequent increase in the number of cases associated with the entry of new serotypes (Fogaça, 2015; Fogaça and Mendonça, 2017). The distribution of serotypes is shown in Table 2.

Figure 4: Brazil's Southern Region: Incidence of dengue cases (January / 2007- March / 2024)



Source: the authors

Table 2: Southern Brazil: Dengue serotypes - 2014-2024*

State	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Paraná	1, 2, 4	1, 2, 4	1, 2, 3, 4	1, 2, 4	1, 2, 4	1, 2, 4	1, 2, 3, 4	1, 2	1, 2, 4	1, 2, 3	1, 2, 3, 4
Santa Catarina	1	1	1		1, 2	1, 2	1, 2, 3	1, 2	1, 2, 3, 4	1, 2, 3	1, 2, 4
Rio Grande do Sul	1, 4	1, 4	1, 2	1	1, 2	1, 2, 4	1	1	1, 2	1, 2	1, 2

DENV1, DENV2, DENV3 and DENV4.

*Data available from January 2014 and March 2024.

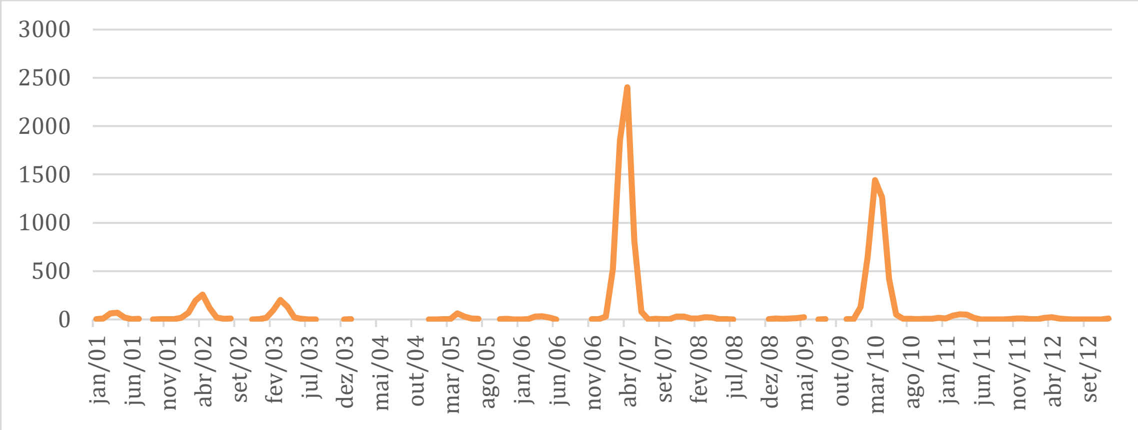
Source: MS, 2024.

The data on serological classification available from DATASUS (MS, 2024) does not represent all cases (underreporting) and, in most instances, does not help to classify the intensity of the disease by the type of virus circulating. However, the official data does make it possible to characterize viral circulation, even if it shows only a partial picture of the extent of the disease. Paraná has recorded all four types of dengue associated with major epidemics, such as the one that occurred between 2015 and 2016, and the spread of the disease after 2020. Santa Catarina, which shares a border with Paraná, has reported more types circulating since 2020; Rio Grande do Sul, with the exception of 2019, has reported two types circulating each year. Particularly for Rio Grande do Sul, the data for the years 2020 to 2024 do not indicate that the intensification of the disease was caused by the entry of new serotypes. It is therefore important to analyze the climatic elements during this period.

To illustrate the relationship between climatic conditions and the incidence of dengue, we looked at the municipality of Maringá, in the state of Paraná, where the disease is endemic. Graphs of probable cases of the disease between 2001 and 2012 (Figure 5) and between 2013 and 2024 (Figure 6) were created to investigate this issue.

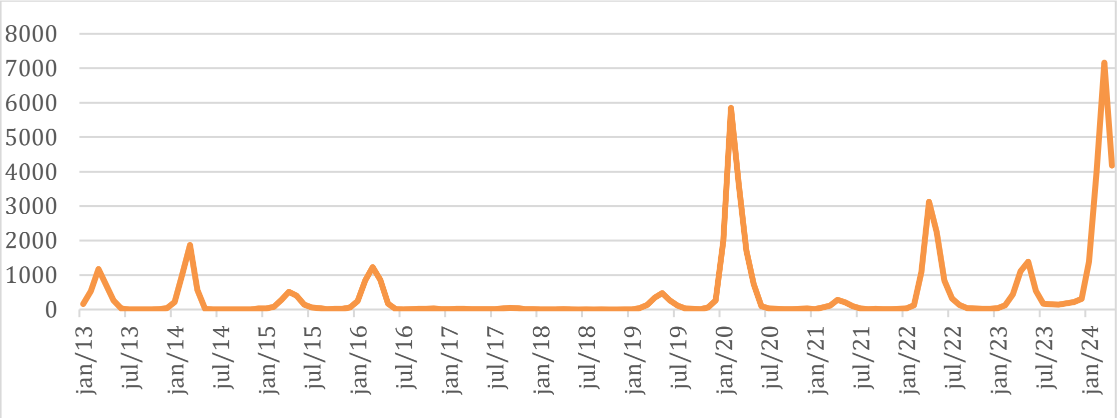
Figure 5 shows two major peaks of the disease in Maringá, the first in 2007 and then in 2010, which was less intense. The second graph (Figure 6), with data from 2013 to 2024, shows two peaks, the first in 2020 and then at the beginning of 2024. Both years saw the circulation of the four dengue serotypes in the state of Paraná, which helps to understand the intensity of the cases. However, in Maringá, only 1 case of type 4 dengue had been confirmed by July 2024 (SINAM, 2024).

Figure 5: Maringá-PR: Probable dengue cases - 2001-2012



Source: DATASUS.

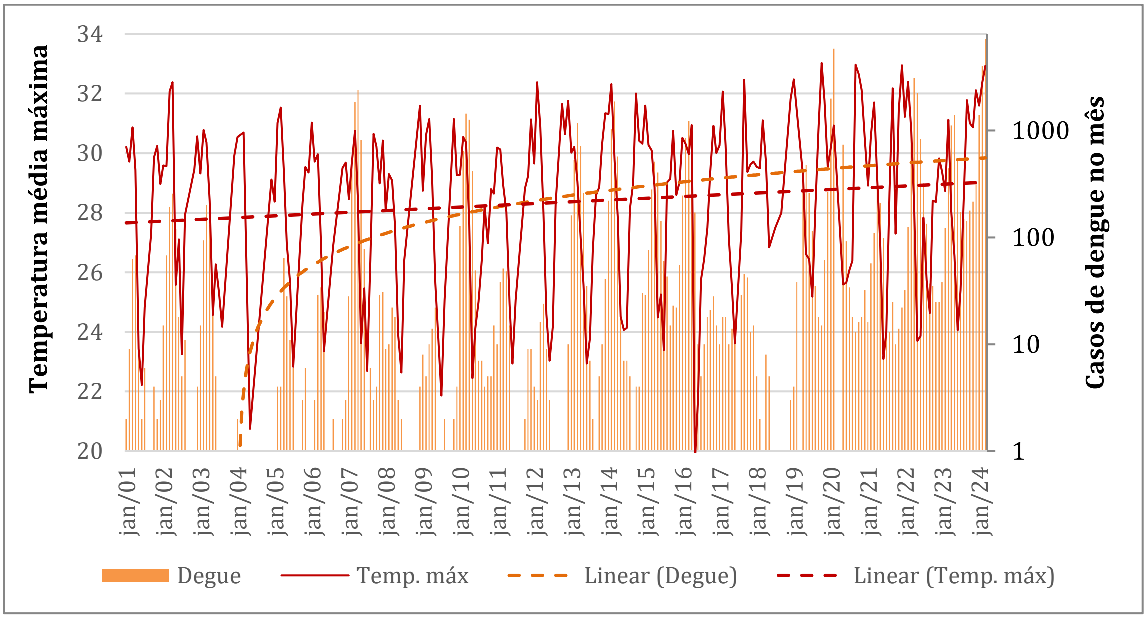
Figure 6: Maringá-PR: Probable dengue cases - 2013-2024*



Source: DATASUS. *Up until March, 2024

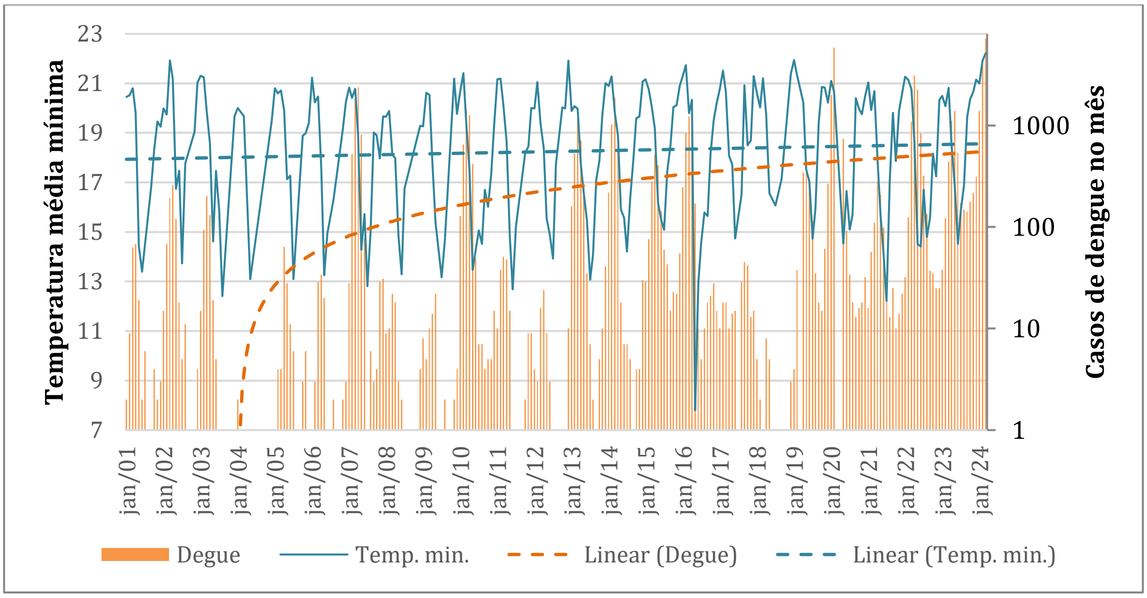
In terms of the climatic influence on the incidence of the disease in Maringá, we have: a) during summer, the maximum temperatures were between 25ºC and 35ºC, and between 15ºC and 25ºC in the winter (Figure 7); b) during summer, the minimum temperatures were between 18ºC and 25ºC and between 10ºC and 20ºC in the winter, with several records below 10ºC (Figure 8).

Figure 7: Maringá - Paraná: Linear trend of average maximum temperatures and dengue cases per month.



Fonte: SIMEPAR/INMET e DATASUS.

Figure 8: Maringá - Paraná: Linear trend of average minimum temperatures and dengue cases per month.



Source: SIMEPAR/INMET and DATASUS.

Between 2001 and 2012, the air temperatures favored the proliferation of the vector; however, the vector's proliferation is clearly limited by the minimum winter temperatures.

Between 2013 and 2024, the maximum temperatures were between 20ºC and 23ºC, with a few exceptions in the winters, which saw occasional drops to 15ºC. There were also peaks above 35ºC, reaching over 40ºC on October 7, 2020. Minimum temperatures in summer averaged between 18ºC and 25ºC, and between 10ºC and 20ºC in winter. 2013 and 2021 were the only years with records below 5ºC. There was also a milder winter in 2023, with a few days when the air temperature was below 10ºC.

Moreover, the milder winter in 2023 may have influenced the proliferation of the vector. In such climatic conditions, cases may start to spread as early as the winter season, considerably increasing the disease transmission period.

Oliveira and Roseghini (2020) yielded similar results when placing *Aedes aegypti* eggs in a BOD Chamber with a photoperiod and a thermo-period to simulate the temperatures recorded in Curitiba - Paraná, which has the lowest average monthly temperatures in the state (according to the Brazilian Climatological Normal 1961-1990). The authors found that temperatures between 12ºC and 22ºC limited egg development (no larvae were found), but when tested at a constant temperature of 26ºC, 121 eggs hatched out of the 416 laid in the simulation.

In both the maximum and minimum temperature graphs for Maringá, an increase in temperatures resulted in an increase in records of the disease, reinforcing the results found by Oliveira and Roseghini (2020) when they highlighted the effects of temperatures between 22ºC and 32ºC (26ºC as used in the simulation), particularly in the winter of 2023, which was the mildest of the entire period.

It is important to stress that, although climatic conditions are key factors for the disease, especially for its vector, and that viral circulation must be accounted for, public policies must also be taken into account in this assessment. In 2016, less severe cases of the disease were recorded in Maringá at a time when the circulation of all four dengue serotypes was also detected in the state. Public policy actions help to understand the rise in the number of cases in 2020 and 2024, as a result of the beginning and end of the COVID-19 pandemic, in which health surveillance actions were prioritized to contain SARS-COV-2. The most severe periods were when health workers were unable to effectively perform their jobs, mainly due to social isolation and quarantines.

6. PUBLIC POLICIES FOR DENGUE CONTROL IN BRAZIL

Brazil has confronted persistent challenges in dengue control since the re-emergence of Aedes aegypti in the late 1970s. The country's initial response relied heavily on chemical control methods, characterized by minimal community engagement, fragmented inter-sector coordination, and limited application of epidemiological tools. This conventional "mosquito-centric" approach has drawn criticism for its narrow focus on vector elimination while overlooking critical social and environmental determinants of disease transmission, including urban inequality and inadequate sanitation infrastructure.

A significant policy shift occurred in 2002 with the establishment of the National Dengue Control Program (PNCD), which decentralized control efforts to municipal governments. The program emphasized integrated epidemiological surveillance, vector control measures, and community participation as fundamental prevention strategies. The subsequent introduction of the Rapid Index Survey for Aedes aegypti (LIRAa) in 2003 enhanced surveillance capabilities by systematically mapping infestation patterns, identifying high-risk breeding sites, and evaluating intervention effectiveness through standardized indices.

Despite these advancements, Brazil's dengue control framework remains constrained by its predominantly reactive nature. Recent innovations, including transgenic mosquito technologies initiated in 2010 and collaborative vaccine development projects, represent attempts to develop more comprehensive solutions. Public education campaigns have simultaneously sought to increase community involvement in prevention efforts. However, persistent over-reliance on insecticide use and mechanical breeding site elimination continues to demonstrate limited effectiveness without complementary investments in urban infrastructure and health education.

The complex ecology of Aedes aegypti in Brazil's urban environments presents ongoing challenges. The mosquito's adaptive life cycle, combined with favorable climatic conditions and widespread urban vulnerabilities - particularly in areas with inadequate water management and sanitation systems - creates persistent transmission hotspots. Climate change effects are exacerbating these challenges by expanding suitable habitats and lengthening transmission seasons.

Recognizing these systemic limitations, the 2020 Integrated Management Strategy for Dengue Prevention and Control (EGI-Dengue) proposed a paradigm shift toward more holistic interventions. This strategy advocates for synchronized implementation of enhanced surveillance systems, preventive measures, targeted vector control, clinical management protocols, and sustained community engagement. The approach emphasizes multi-sector collaboration to address both biological transmission factors and underlying social determinants of disease vulnerability.

While Brazil has made measurable progress in dengue control, the continued predominance of vector-targeted strategies reveals fundamental limitations. Critical gaps in universal sanitation access and health literacy remain unaddressed barriers to effective prevention. Future policy directions must incorporate broader social-ecological perspectives that acknowledge the interconnectedness of urban development, environmental management, and public health. Strategic investments in infrastructure modernization, educational programs, and community-based surveillance systems will be essential for developing sustainable, climate-resilient approaches to dengue control. Such integrated strategies offer the potential for more effective and equitable long-term solutions to Brazil's persistent dengue challenges.

7. CONCLUSION

Most human diseases are directly and indirectly influenced by climatic conditions, and many of them may be aggravated by the climate changes and emergencies that are currently unfolding and will unfold in the near future. The Neglected Diseases – or diseases of poverty, such as dengue, cholera, leptospirosis, etc. are clear evidence of a serious threat to humanity in view of their expansion in the context of global climate warming, especially due to their insufficient or even lack of clinical control. This scenario is further complicated by the association of this risk with the substantial socio-environmental vulnerability of the populations of humid tropical countries.

As a pathogenic complex – the Dengue Complex – this disease requires a multi-causal analysis to develop coping measures based on environmental control. Thus, the control of the *Aedes aegypti* vector is crucial given its role in the transmission of dengue, yellow fever, chikungunya and zyca. Addressing the ecology of the vector (temperature, humidity, rainfall) in urban environments (as is the case in Brazil) can greatly contribute to effective actions to reduce the number of cases of the disease.

The biggest dengue epidemic in history was recorded in 2023 up until mid-2024, with a record number of cases in Brazil accounting for approximately 83% of the world's total cases. This year and a half have also been the hottest in recorded history in the world – in Brazil, associated with intermittent rainfall, the number of cases has hit an all-time high. In recent decades, also due to global climate warming, dengue has been reported in places once untouched by it; such was the case in the southern region of Brazil which, also due to the historical predominance of mesothermal climatic conditions – Humid Subtropical Climate – had no records of the disease. In recent decades, especially in recent years, dengue has spread to all Brazilian states.

Vaccines against dengue have been developed in several laboratories around the world; however, they are still far from the population's reach due to the high production costs, which make them very expensive. The ineffectiveness of public policies to control the disease vector in Brazil – a mosquito-centric model – was apparent long before the vaccines were developed. The impact of the COVID-19 pandemic meant that the government and the population had to prioritize the issue of dengue. However, it continued to be recorded and, as soon as climatic conditions/poor sanitation allowed and human bodies were more exposed, it once again struck the country's population.

Since climate influences the vector, it has an indirect effect on the incidence of dengue; we know little about the virus itself. Given the difficulties in controlling the disease and the present and future context of global climate change and emergency, associated with chaotic urbanization and environmental sanitation, it is estimated that the spread and intensification of the disease will be of great concern to public managers and the population in general. Science has a long way to go to make an effective contribution to combating this problem.

Note.

Data on the disease was collected via DATASUS – the Information Technology Department of the Brazilian Unified Health System – between 2001 and 2024 (up to March 2024). The data for municipalities in the southern region of the country was processed using monthly values, a time format available online. The population figures from the 2000, 2010 and 2022 censuses (IBGE, 2024) were used to calculate the incidence of the disease; all for a range of 100,000 inhabitants.

Climate data was obtained by year from the Brazilian Meteorological Institute (INMET, 2024) and treated according to daily records and monthly averages.

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