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Loss and damage affecting the public health sector and society resulting from flooding and flash floods in Brazil between 2010 and 2014 - based on data from national and global information systems

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Abstract *This article outlines the results of a descriptive study that analyses loss and damage caused by hydrometeorological disasters in Brazil between 2010 and 2014 using the EM DAT (global) and S2iD (national) databases. The analysis shows major differences in the total number of disaster events included in the databases (EM-DAT = 36; S2iD = 4,070) and estimated costs of loss and damage (EM-DAT – R$ 9.2 billion; S2iD – R$331.4 billion). The analysis also shows that the five states most affected by these events are Santa Catarina, Rio Grande do Sul, Minas Gerais, São Paulo and Paraná in Brazil's South and Southeast regions and that these results are consistent with the findings of other studies. The costs of disasters were highest for housing, public infrastructure works, collectively used public facilities, other public service facilities, and state health and education facilities. The costs associated with public health facilities were also high. Despite their limitations, both databases demonstrated their usefulness for determining seasonal and long-term trends and patterns, and risk areas, and thus assist decision makers in identifying areas that are most affected by and vulnerable to natural disasters.*

Key words *Natural disasters, Hydrometeorological disaster, Flooding, Damage assessment, Database*

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Introduction

Disaster is defined as a serious disruption in the functioning of a community or society involving widespread human, material, economic and environmental loss and damage, which exceeds the ability of the affected community or society to cope using its own resources[1]. Climate events largely associated with unplanned growth in cities in areas that are unsuitable for occupancy are responsible for the occurrence of natural disasters[2].

These events are the result of a combination of four factors that have implications for public health: 1) the occurrence of natural threats; 2) an exposed population; 3) the social and environmental vulnerability of this population; 4) lack of capacity to reduce the potential risks and public health consequences of disasters[3].

Although human history has always been marked by natural disasters, this problem is increasingly part of everyday life as the number and extent of disasters has increased sharply[4,5], resulting in over 3.3 million registered disaster -related deaths over the last 40 years[6]. The economic consequences of disasters between 2000 and 2010 amounted to a trillion dollars, and disaster relief during the same period accounted for around 20% of all humanitarian aid[7]. Disasters have a significant impact on agriculture and related systems and adversely affect the health and education sector, which in turn has negative consequences for the long-term economic and social development of affected communities[8].

Brazil occupies a prominent position in the world in terms of number of natural disasters over recent years. An assessment of the occurrence of natural disasters during the period 1991 and 2010 showed that there were 31,909 disasters in the country[2] and an increase in the frequency and intensity of storms and the number of people directly and indirectly affected by extreme climate events[9]. Although this increase is partly due to improvements in the recording and dissemination of information related to disasters, these figures are also the result of an increase in the rate of urbanization, deforestation, environmental degradation and climate change[2,4,10].

The most common types of disaster in Brazil during this period were, in order of frequency: droughts, flash floods, flooding, strong winds, hailstorms, erosion, forest fires, landslides, tornados, pluvial flooding and frost. Although the second most common type of disaster, flash floods accounted for most human losses and impacts, followed by flooding[11]. Disasters related to alterations in the normal water cycle, such as flash floods, flooding and pluvial flooding, are known as hydrometeorological disasters[12]. Due to Brazil's size, diverse atmospheric conditions and a large hydrological network comprising of over 55,457 km of watercourses, all regions of Brazil are subject to extreme hydrometeorological events at some time throughout the year[2].

Apart from causing human damage, flooding, flash floods and pluvial flooding have an impact on the environment and human development[3]. Socioeconomic effects include: damage and destruction of income sources and physical structures, such as houses, buildings and roads; breaking of flood protection dykes and fuel tanks; interruption of water, electricity and gas supplies, and transport and communication services; interruption of health, education and commercial services; adverse effects on agricultural activities; and loss and damage of personal goods and items of sentimental value[3].

In 2012, the Law Nº 12608/12 created the Integrated Disaster Information System (*Sistema Integrado de Informações sobre Desastres* - S2iD), a joint database run by the Ministry of National Integration and utilized by civil defense agencies at national, state and local level[13]. Decision makers also use global databases[14] to help identify areas that are most affected by and vulnerable to natural disasters, the most prominent of which is the Emergency Events Database (EM-DAT). The EM-DAT was created in 1988 and is run by the Centre for Research on the Epidemiology of Disasters (CRED) at the Catholic University of Leuven in Belgium.

Comparative studies show significant differences between disaster databases concerning information regarding the number of people affected by disasters and loss and damage[9,14,15]. Despite an unquestionable focus on the human losses and impacts caused by disasters, little research has been carried out into disaster-related material losses. This study therefore aims to estimate, compare and contrast the material losses caused by hydrometeorological disasters in Brazil between 2010 and 2014 based on information obtained from the EM-DAT and S2iD databases.

Materials and methods

This paper describes the results of a descriptive study that compared and contrasted information contained in the EM-DAT (international) and S2iD (national) databases. Using secondary data

obtained from these databases, the study estimated the occurrence of, and loss and damage caused by, hydrometeorological disasters in Brazil during the period 2010 to 2014.

Disasters must meet at least one of the following EM-DAT entry criteria: 10 or more deaths; 100 or more affected people; declaration of a state of emergency or calamity; there is a call for international assistance[16].

The S2iD compiles information on disasters in Brazil including location (municipality), type of disaster, date of occurrence, causes and effects, and human, material and environmental loss and damage. This information is recorded on a specific form filled in by a member of the Civil Defense Agency or locally responsible government agency, which must be sent within 120 hours after the occurrence of the disaster.

All hydrometeorological disasters contained on the EM-DAT and S2iD databases that occurred between 2010 and 2014 and resulted in loss and damage were considered eligible for the study.

The relevant data was inputted into an Excel spreadsheet using the following categories: year, type of disaster, number of occurrences, the cost of resulting loss and damage (in Brazilian Real – R$), and, for disasters registered on the S2iD, type of loss and damage.

The costs of loss and damage on the S2iD and EM-DAT are calculated in Brazilian Real (R$) and US dollars, respectively. To enable comparison, loss and damage in dollars was converted to Brazilian Real based upon the average annual exchange rate obtained from the Brazilian Central Bank's website[17].

Spending on housing made through the *Minha Casa Minha Vida* (My House, My Life) program was calculated based on total spending since the program was created in 2009 up to 15 October 2014 using information available on the website *Portal Brasileiro de Dados Abertos - Indicadores sobre Minha Casa Minha Vida*[18].

Health sector spending between 2010 and 2014 was calculated based on the total amount of funding for the purchase of equipment, permanent material, and material for the Mobile Emergency Care Service (*Serviço de Atendimento Móvel de Urgência* – SAMU), primary health centers, and health services and pre-hospital fixed services provided by the comprehensive emergency care network throughout Brazil. This information is available on the Health with More Transparency website of the Ministry of Health[19].

The study used only secondary data from the databases that is available to the public. As a result, after written inquiry, the Research Ethics Committee of the University of Brasília (CEP -UnB, acronym in Portuguese) waived the requirement to apply for ethical approval.

Results

The analysis of information on hydrometeorological disasters contained in the EM-DAT and S2iD databases concerning flooding, flash floods and pluvial flooding in Brazil between 2010 and 2014 showed that there were considerable differences in information, both in terms of the number of occurrences (36 compared to 4,070, respectively) and loss and damage (9.2 compared to R$ 331.4 billion, respectively). Loss and damage caused by hydrometeorological disasters in Brazil registered by the EM-DAT was less than that recorded by the S2iD (Table 1) for each year during the period 2010 to 2014.

The analysis of the data obtained from the S2iD also shows that the five states most affected by flooding, flash floods, and pluvial flooding during the period were Santa Catarina (n = 826), Rio Grande do Sul (n = 792), Minas Gerais (n = 461), São Paulo (n = 299) and Paraná (n = 297), which are all located in the South and Southeast Regions of the country (Figure 1). Flash floods were most frequent in Santa Catarina (n = 627), followed by Rio Grande do Sul (n = 607), Minas Gerais (n = 213), Paraná (n = 198), Bahia (n = 132), São Paulo(n = 130), Espírito Santo (n = 120), Pernambuco (n = 116), Mato Grosso (n = 52) and Alagoas (n = 46). The 10 states most affected by flooding were Minas Gerais (n = 213), Rio Grande do Sul (n = 163), Amazonas (n = 162), Santa Catarina (n = 153), São Paulo (n = 94), Mato Grosso do Sul (n = 91), Pará (n = 65), Paraíba (n = 63), Rio de Janeiro (n = 62) and Paraná (n = 36). Pluvial flooding was most frequent in the states of São Paulo (n = 75), Paraná (n = 63), Santa Catarina (n = 46), Minas Gerais (n = 35), Bahia (n = 33), Rio de Janeiro (n = 25), Amazonas (n = 24), Rio Grande do Sul (n = 22), Mato Grosso do Sul (n = 19), and Espírito Santo (n = 12).

The S2iD data also showed that loss and damage caused by hydrometeorological disasters was greatest in São Paulo (R$ 98.5 billion), Rio de Janeiro (R$ 98.2 billion), Espirito Santo (R$ 37.7 billion), Santa Catarina (R$ 31 billion) and Rio Grande do Sul (R$ 20.2 billion), which are, again, all located in the South and Southeast Regions of the country (Figure 2).

The analysis of loss and damage cost data shows a decreasing trend over the period (Table 1): in 2014 the cost was R$ 6.9 billion, a 61% reduction in relation to 2010 (R$ 205.7 billion). Damage to housing and public infrastructure works was particularly high between 2010 and 2011, compared to the previous period. For example, the cost of damage to houses in 2010 was R$ 136 billion, compared to R$ 2 billion in 2014. This peak in 2010 and 2011 is due to high levels of damage to housing and public infrastructure in the states of Rio de Janeiro, São Paulo, Minas Gerais, Santa Catarina, Paraná and Pernambuco in 2010, and in the states of Espírito Santo, São Paulo, Rio Grande do Sul and Santa Catarina in 2011 (Figure 3).

According to S2iD data, destruction or damage of housing accounted for the large majority of total loss and damage (58.7%), followed by public infrastructure works (27.9%), and public facilities (9.9%) (Figure 4).

The data showed that the cost of damage to housing caused by hydrometeorological disasters between 2010 and 2014 was R$ 194 billion, while public spending on housing between 2009 and 2014 was R$ 89 billion, through the *Minha Casa Minha Vida* program, and spending in the health sector between 2010 and 2014 on the purchase of permanent material and the construction of facilities was R$ 4 billion. During the same period, the cost of loss and damage caused by hydrometeorological disasters to public health facilities was R$ 1.2 billion.

Table 1. Costs associated with loss and damage caused by the hydrometeorological disasters occurring between 2010 and 2014 included in the S2iD and EM-DAT (R$ billion).

Database/ Year	2010	2011	2012	2013	2014
S2iD	205.71	109.53	0.023	9.24	6.89
EM-DAT	2.82	3.35	0.67	2.34	0

Discussion

The present study describes variations in the notification of occurrences of hydrometeorological disasters and associated loss and damage in Bra-

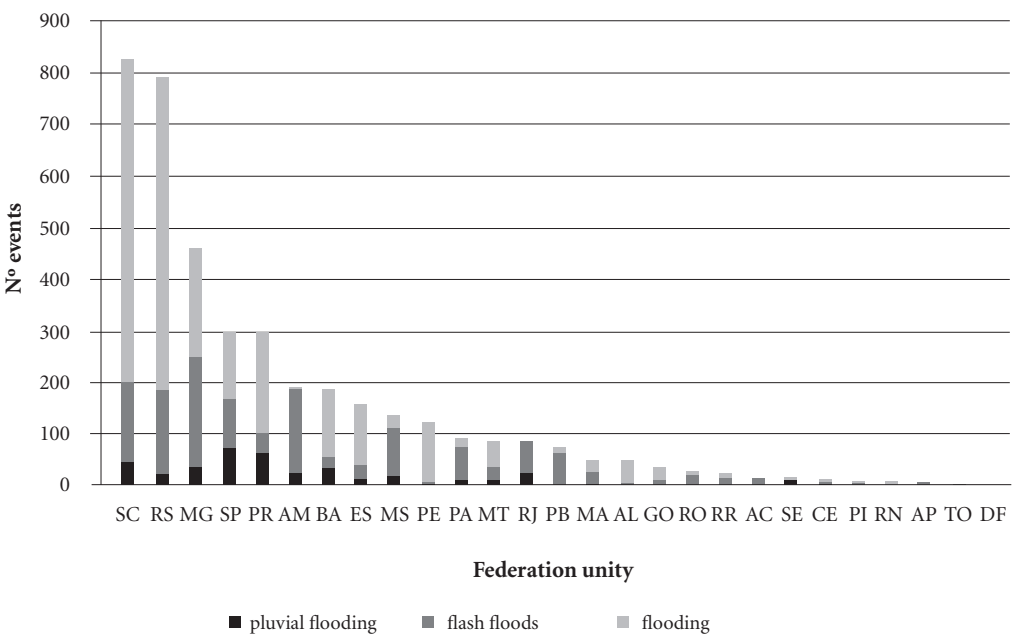

Figure 1. Number of hydrometeorological disasters between 2010 and 2014 by state included in the S2iD.

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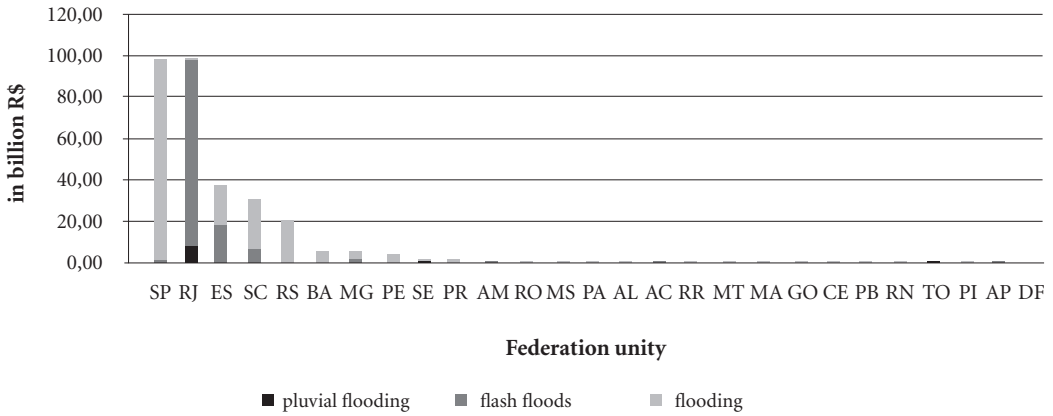

Figure 2. Loss and damage caused by hydrometeorological disasters occurring between 2010 and 2014 included in the S2iD by state (R$ billion).

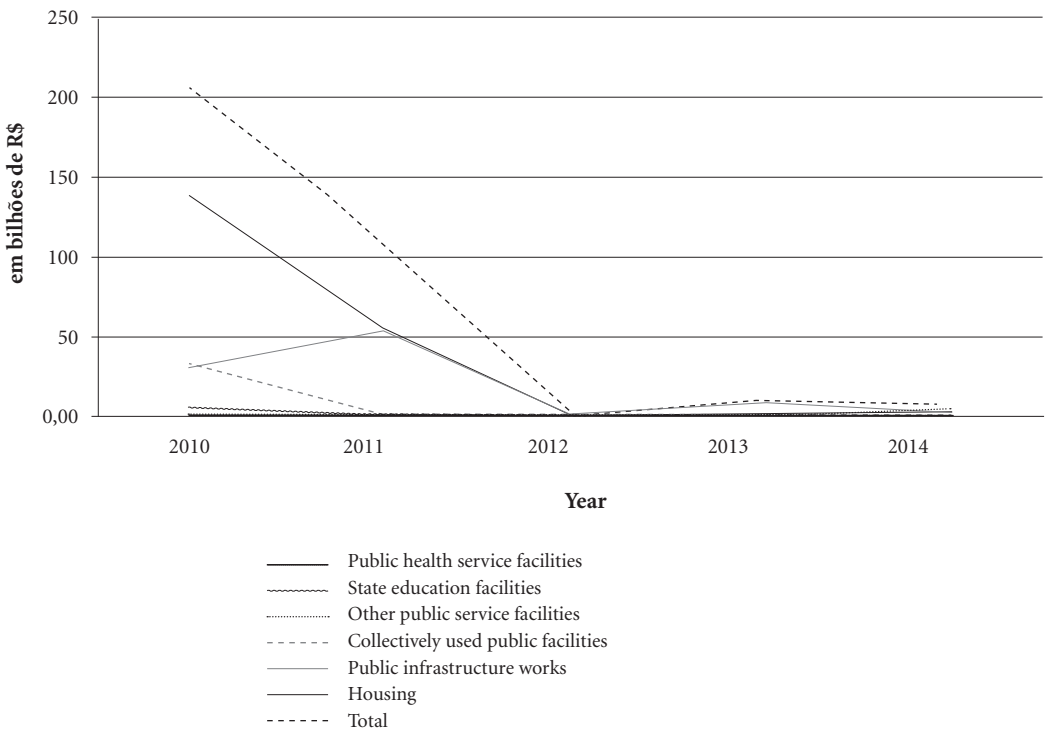

Figure 3. Loss and damage caused by hydrometeorological disasters in Brazil by year between 2010 and 2014 according to the S2iD (R$ billion).

zil. The number of events registered by the S2iD was notably greater than that recorded by the EM-DAT. Furthermore, the analysis of S2iD data showed that occurrences and loss and damage between 2010 and 2014 was greatest in the states of São Paulo, Minas Gerais, Espírito Santo, Santa

Catarina, Rio Grande do Sul, and Paraná. Both databases revealed a downward trend in disasters during the study period.

A comparative analysis of disaster notifications in both databases during the period in question showed that coverage of hydrometeorological events (flooding, flash floods and pluvial flooding) was considerably greater (113 times) in the S2iD. Furthermore, the estimated cost of loss and damage was 36 times greater according to the S2iD.

The EM-DAT estimates costs based on damage to property and agriculture[16], while the S2iD only considers loss and damage related to public health, education and other service facilities, housing and public infrastructure works[20]. Since the S2iD does not consider agriculture, it would be expected that estimated costs are lower than those recorded in the EM-DAT; however, this was actually not the case. This is probably due to the adoption of different event inclusion criteria for each database, which leads to a considerably higher number of notifications in the S2iD. This observation corroborates the findings of other studies that have shown that the EM-DAT records a significantly lower number of events than Brazilian disaster data sources[9,10].

The EM-DAT has been compiling information on disasters around the world since 1900 using various sources, such as agencies of the United Nations (UN), nongovernmental organizations, insurance companies, research institutions and news agencies[9,14]. The database has global reach and credibility among universities and research institutions since it clearly presents data collection and storage methodology[10] and is used by various institutions, including the UN, to inform natural disaster mitigation and prevention actions and policies[21].

The S2iD was created in 2012 as a joint database used by national, state and local civil defense agencies[13] and offers up-to-date information on disaster prevention, mitigation, alert, response and recovery across the country[13].

The Civil Defense Agency or locally responsible government agency must fill in specific forms and documents available on the S2iD and send them to the SINPDEC within 120 hours (five days) after the occurrence of the disaster[22].

According to Ministerial Order Nº 526/2012-MI, the aim of the S2iD is to computerize the transfer of central government funding to state and local governments in regions hit by disasters where a state of emergency or calamity has been declared[20,23].

A state of emergency or calamity is declared to return a situation to normal at the earliest feasible time. It is the Civil Defense Agency's task to restore normality by working together with other institutions and society[22]. A state of emergency is understood as an intense and serious change in normal conditions in a given municipality, state or region that partially compromises response capacity, while a state of calamity is an intense and serious change in normal conditions that considerably compromises response capacity. A state of public calamity is the consequence of important, intense, and significant human, material and environmental loss and damage, which is often irreversible or where recovery is particularly difficult[20].

According S2iD data, the five states with the largest number of notifications of hydrometeorological disasters between 2010 and 2014, in or-

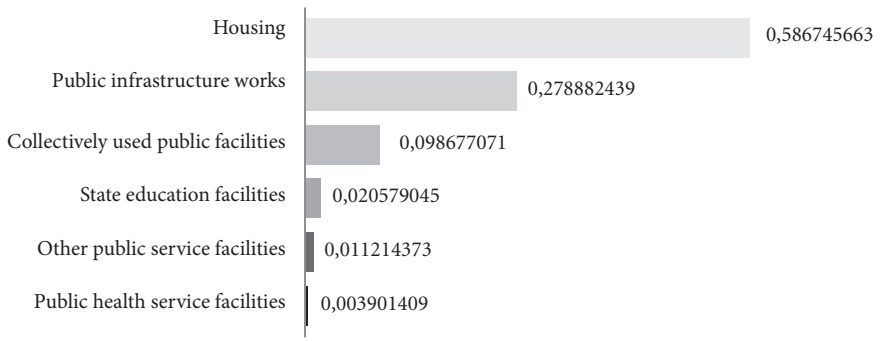

Figure 4. Loss and damage caused by hydrometeorological disasters in Brazil between 2010 and 2014 by type, according to the S2iD.

der of frequency, were Santa Catarina, Rio Grande do Sul, Minas Gerais, São Paulo and Paraná, while the greatest losses were registered in the states of São Paulo, Rio de Janeiro, Espírito Santo, Santa Catarina and Rio Grande do Sul. All these states are located in Brazil's South and Southeast regions. These results are consistent with the findings of other studies[2,11].

This situation is probably associated with unplanned urban growth and environmental degradation in these regions[5] and heavy rainfall events during the rainy season[2]. Furthermore, high population density in these regions means that a greater number of people and buildings are exposed and vulnerable to disasters[24], thus meaning that impacts tend to be more severe and costly[8].

Apart from material losses, the damage and destruction of housing affects the physical and emotional integrity of residents[25]. Over half of the losses and damage caused by the hydrometeorological disasters included in the S2iD for the period 2010 to 2014 were housing-related. This could be explained by rapid urban growth, evidenced by the increase in the number of municipalities in Brazil over the last two centuries, from 1,121 municipalities in 1900 to 1,890 in 1950, and reaching 5,565 in 2010[26]. Unplanned urban growth in Brazil's cities has led to the construction of housing on areas that are unsuitable for occupancy and therefore more vulnerable to disasters. Hydrometeorological disasters present a major human development challenge, particularly in rapidly growing cities in developing countries[8].

The *Minha Casa Minha Vida* program, coordinated by the National Housing Secretariat of the Ministry of Cities, aims to make housing accessible to families with a gross monthly income of up to R$ 1,600. Spending on housing through this program up to October 2014 was R$ 89 billion[18]. The figures show that the costs of damage to housing caused by hydrometeorological disasters between 2010 and 2014 (R$ 194 billion) were 2.18 times greater than spending during the same period through the *Minha Casa Minha Vida* program. This situation shows that it is necessary to increase spending on housing and the prevention of potentially damaging natural events.

Despite comprising a relatively small proportion of total disaster-related costs (0.39%), another aspect that deserves highlighting is the damage caused to public health facilities (R$ 1.2 billion): the cost of damage caused by hydrometeorological disasters to public health facilities was equivalent to 30% of total government spending on material and equipment and new health facilities during the period in question (R$ 4 billion).

The Pan American Health Organization (PAHO) estimates that 73% of the population and 67% of health facilities in Latin America and the Caribbean were located in risk zones in 2012. Between 1982 and 2012, at least one in eight health facilities in Latin America was severely affected by natural disasters, interrupting operations and leaving over 24 million people without any access to health services over a period of months or even years[27,28].

The main limitation of this study is that it is difficult to verify the reliability and accuracy of secondary data. Inconsistencies were found between EM-DAT and S2iD data regarding notifications of hydrometeorological disasters and, consequently, in loss and damage estimates. This problem may be due to the use of different event inclusion criteria and data collection and storage methods, the low number of disasters registered by EM-DAT for Brazil, and the overestimation of loss and damage by local and state government managers in an attempt to obtain external funding. The main aim of the forms used for the S2iD is disaster notification, rather than measurement of overall loss and damage caused by a disaster. Disasters must be notified within a short space of time (120 hours), meaning that the information given about damage is not likely to be an accurate estimate of overall loss and damage.

A report produced by the World Bank in 2014 specifies measures that can be adopted to minimize the effects of disasters, including the creation of an effective national disasters fund, strengthening the financial management of disaster aid programs and improvements in disaster data collection and management systems[29]. Despite limitations associated with the use of varying data collection concepts and methodologies in different countries, the EM-DAT is an easily accessible global disaster database, while the S2iD provides records of the type of disasters covered by this study over the period in question.

These kinds of databases are valuable tools for epidemiological research and enabling, for example, the creation of historical data to assess the vulnerability of particular states or regions and inform budget forecasting[30,31]. Improving the quality of disaster databases would therefore enhance a range of monitoring and research possibilities. Understanding the causes and im-

pacts of flooding and the planning and funding of measures to minimize disasters should be part of current development thinking and included in wider development goals[8].

Conclusions

The interdisciplinary and intersectoral nature of disaster prevention and response requires public health managers to have a broad perspective of the process and the formulation of policies and actions geared directly towards addressing the social and environmental determinants of disasters[3]. Quality data concerning the causes and consequences of disasters is therefore critical to inform prevention and mitigation plannning and intersectoral responses. However, despite the existence of a special department of the Ministry of Health – the Health Surveillance Secretariat – where such matters are discussed, this topic is given little attention in the Public Health field in Brazil.

The analysis of large databases allows researchers to identify seasonal and long term trends and patterns, and risk areas[3], and this study shows the usefulness of national and international information systems. The EM-DAT global database uses stricter event inclusion criteria and therefore only more specific, medium and large-scale disasters are entered, leaving out many small but relevant disasters; while the coverage of the S2iD national database is wider and includes small-scale disasters. However, the latter system is likely to notify events as disasters often when they do not meet the appropriate definition of disaster - "an event that exceeds local response capacity".

This study aims to promote debate among government managers, especially those working in the health sector, regarding the occurrence of and damage caused by desasters to inform intersectoral prevention and mitigation policies and improve disaster preparedness and response. The EM-DAT global database compiles data on disasters in Brazil and is particularly useful for national government managers, while the S2iD includes data on national, state and local-level disasters, making it an excellent source of information for national, state and local government managers.

Certainly the worst aspect of disasters is loss of human life, injury and other health impacts and the social suffering they induce. However, the assessment of loss and damage is important to inform decision making regarding the allocation of resources and assistance to the affected population and the prevention of further loss and damage from future events. The present study therefore serves as a tool to promote debate on this topic and mobilize government managers and society. The challenge of coping with disasters is common to many cities and tends to be accentuated by climate change. It is therefore necessary to reflect on this issue and develop sustainable solutions to ensure the coexistence of society and environment[32].

Freitas et al. affirm that in the health field, health status depends upon ways of developing processes that characterize the structure and dynamics of a society. This involves both social and economic processes and resultant environmental changes that trigger changes in climate and water cycles and widescale degradation of available natural resources. Thus, while heavy rains, flooding, drought, landslides and cyclones are natural phenomenoms, disasters are social phenomenoms associated with current models of social and economic development[3].

Collaborations

AC Minervino and EC Duarte participated equally in all stages of preparation of the article.

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