Periódico Eletrônico
Fórum Ambiental da Alta Paulista
ISSN 1980-0827 – Volume 17, número 2, 2021

Flash-floods control

Emerson Luís Pawoski da Silva
Doctoral Student in Geography, UFPR, Brasil.
em.pawoski@gmail.com

Maria Helena de Carvalho Rodrigues Silva
Doctoral Student in Geography in Geography, UERJ, Brasil.
mhcrsilva@gmail.com

Francisco de Assis Mendonça
PHD Professor of Geography, UFPR, Brasil.
chico@ufpr.br

ABSTRACT
Flash-Floods are among the hydrological disasters that most damage life and structures in Brazil. The frequency and impacts of flash-floods may become an increasing problem due to the future scenario of an increase in global temperature causing intense precipitation. Through the literature, the aim of this study was: clarify how flash-floods occur; present national policies and legal provisions related to disaster risk management and what actions are suggested for prevention and response. Flash-floods are intense water superficial movements that are not dependent on watercourses. They are depending of warm and humid climate, rugged terrain and waterproofing land cover. All over the planet, actions are proposed for these disasters. In Brazil, Civil Defense acts through monitoring, diagnosis, prognosis and structural actions, i.e., physical, and non-structural, or regulatory. The structural actions to flash-floods are focused on land cover and mainly vegetation, while non-structural actions focus on zoning risk areas and assisting of affected populations. These measurements can be improved with social data, as income, and meteorological data, as air mass movement, temperature, humidity and clouds. Information about flash-floods, responsible agencies and measures can be used to help manage the risk of these disasters.

KEY-WORDS: Climate change. Planning. Water.

1 INTRODUCTION

The changes of landscapes interfere with its components, benefiting or harming them. These transformations are common, however, when they harm humanity, they are also understood as dangerous events. Not all natural events cause damage, since this occurs when their magnitude is beyond expectations and there are no actions of resistance and resilience (MONTEIRO; MENDONÇA, 2011).

The expression *Hazard* is commonly adopted as a synonym for danger or the possibility of a harmful event. The term vulnerability is associated with social groups with some type of exposure to a harmful event and susceptibility is related to environmental aspects favorable to the harmful event (BRASIL, 2007; NOBRE; MARENGO, 2017). Vulnerability is influenced by income and education. It is increased from urban centers to marginal areas (BUFFON, 2018). Risk is, therefore, the sum of the degree of damage and the possibility of its occurrence. When risk ceases to be a threat and becomes a real event, it is called an environmental disaster or accident (SAUSEN; LACRUZ, 2015). The risk areas are, in short, inhabited areas where harmful environmental events can be manifested (BRASIL, 2007). The damages, in these places, can be private or public, and in both ways there are specific social groups that are more affected (MONTEIRO; MENDONÇA, 2011).

For Nobre and Marengo (2017), the spatial organization of social groups in a place determines how they experience environmental disasters, and it is commonly the disadvantaged, as servants, immigrants and slaves, who suffer more (FREITAS, 2011). Mendoça (2010, p. 156, *translated*) comments:

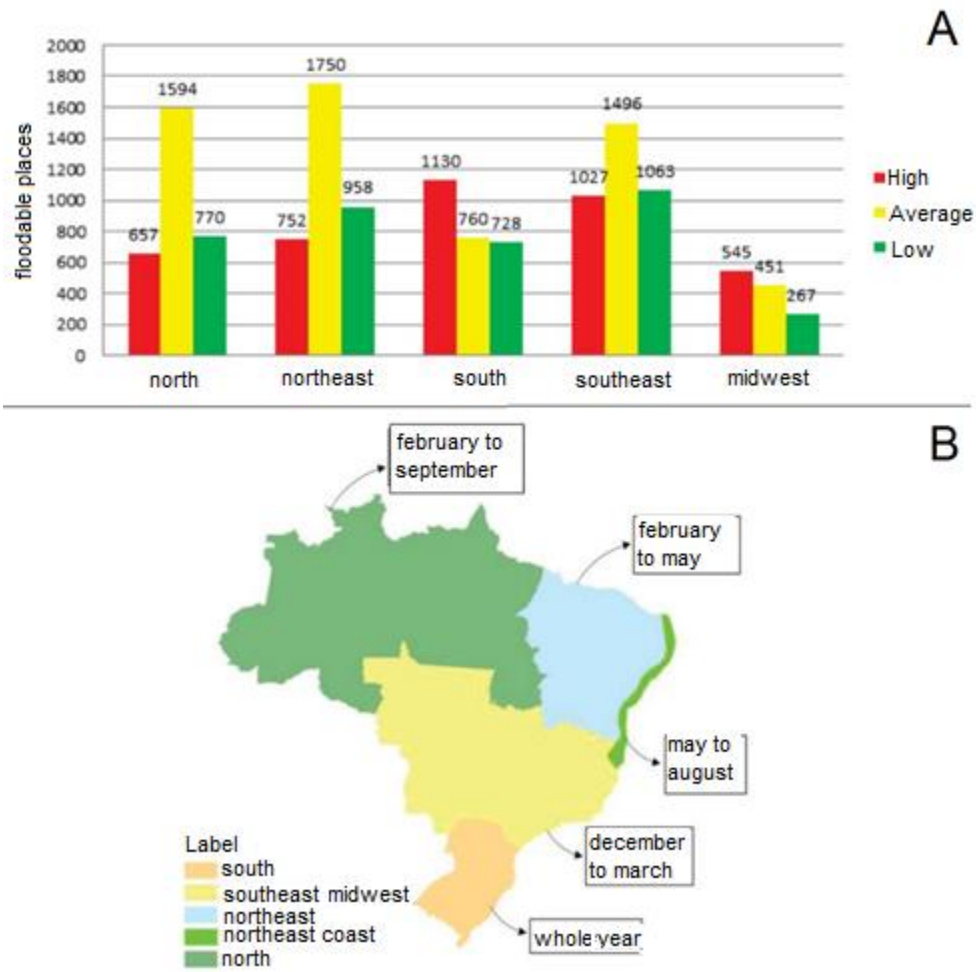
> [...] urban socio-environmental risks are related to the intertwined phenomena of natural and social contingencies that destabilize the living conditions of urban societies; they show elements and factors of a natural (environmental) and social (cultural, political, economic and technological) order.

Despite the emergence of new technologies and artifacts, the risks of natural disasters increased with the growth of population and expansion of territories (FREITAS, 2011, MONTEIRO; MENDONÇA, 2011). Urban centers are the places that most consume goods and services, and consequently interfere in environmental processes (ADLER; TANNER, 2015), however the marginal areas have less resilience and it constitutes issues of environmental injustice. Low income, lack of territorial planning, lack of legal provisions related to risk areas and lack of professional training are among the causes of environmental disasters. Suggest resolutions are: adaptation, elimination or risk reduction (BRASIL, 2007).

The climate changes affect rainfall intensities because air humidity and precipitation are associated with temperature (FREITAS, 2011, MONTEIRO; MENDONÇA, 2011). The IPCC (Intergovernmental Panel on Climate Change) presents that the impacts of climate change can be direct (lives and structures), ecological and pathological. Certain pathogens, for example, are more adapted to warmer temperatures and humid environments (FREITAS, 2011).

Between 1995 and 2015, Brazil was considered one of the 10 countries most affected by natural disasters (NOBRE; MARENGO, 2017), with 85% caused by excess or lack of water (MONTEIRO; MENDONÇA, 2011; MARENGO et al., 2021). From 1970 to 2012, 8.835 natural disasters were recorded, related to approximately 2 million deaths. There were 302 disasters In 2011, which 106 were associated with intense precipitation (fluvial and flash floods and landslides) (NOBRE; MARENGO, 2017). In the southern region of the country, for example, storms and floods, fluvial and flash, are the disasters that cause the more deaths (SAUSEN; LACRUZ, 2015). According to frequency (<5 years; 5 to 10 years; > 10 years) and impacts (life, structures and essential services), the National Water Agency (NWA) classified regions in Brazil according to vulnerabilities to flooding (Figure 1).

Figure 1 – Vulnerability classes and hydrological disasters.



Source: ANA (2014).

MARENGO et al., (2021) made projections for 3 scenarios of temperature increase in Brazil, 1.5; 2 and 4°C, checking the gradual increase in the frequency and magnitude of flash and fluvial floods and landslides. Until 2100, the most affected regions will be the south and southeast, mainly in mountainous areas. However, the northeast region has less condition to manage with these disasters. These projections corroborate reanalysis studies, mainly on the south (MENDONÇA, 2017, MARENGO et al., 2021).

There is the hypothesis of the possibility of an increased risk of hydrological disasters, especially flash floods due to changes in climate and land cover in Brazil. This text aims to: clarify how flash floods occur; present national policies related to disaster risk management and what actions are suggested for prevention and response. This data can help research and action for these disasters.

2 METHODOLOGY

This bibliographical study was produced by searching for the keywords: inundação repentina; *flash-flood*; risco; *risk*; desastre; *disaster*; clima; *climate* on the indexers Portal de Periódicos CAPES and WorldWideScience. Books and articles related to flash floods were selected, according to the concept of high energy runoff adopted by the Civil Defense (BRAZIL, 2017) and presented by Brasil (2007), Ufsc/ Ceped, (2013) and Marengo et al., (2021). The data was compared with Civil Defense documents (BRASIL, 2007, 2017, 2021).

The theoretical review presented, through the literature, what are and how flash floods occur; how Civil Defense works in the management of natural disaster risks associated with climate change; what are the suggested actions to prevent and respond to flash floods, with emphasis on land cover and procedures.

3 RESULTS

3.1 Flash floods and land cover

The regions of Brazil are influenced by different air masses. North and northeast to the center-south with EAAR (Equatorial Atlantic); north to the state of Rio Grande do Sul with ECAR (Continental Equatorial); southeast with TAAR (Tropical Atlantic); south with PAAR (Polar Antarctica); and south to south center with TCAR (Tropical Continental). The difference between the regions occurs due to several factors, as the distance to the Atlantic Ocean and the extension of the areas. This is a generic configuration, since the masses interact with each other and with geographic factors, creating subtypes (BORSATO; MASSOQUIM, 2020, *translated*):

> The air masses that act in the climates of Brazil have their centers of origin outside the Brazilian territory, except for the Continental Equatorial mass. As they advance, they impose their characteristics, on the other hand, they assimilate the characteristics through which they pass. In this way, its properties are frequently modified in its attributes, which change as a mass assimilates traces of the area through which it passes, thus, it can gain or lose moisture or heat, increase or decrease atmospheric pressure (BORSATO; MASSOQUIM , 2020, p. 29).

As the temperature of a given air mass changes, molecules may condense with the formation of clouds and precipitation (MONTEIRO; MENDONÇA, 2011). Considering clouds as storage spaces and the different rainfall intensities as transport and movement systems (Chart

1), Bari et al., (2021), presented that dams and reservoirs also cause flash floods when they release large amounts of water.

Chart 1 – Precipitation and rain classes.

Rain classes	Precipitation (mm³/ day)
Dry Day	P < 2,2
Very light rain	2,2 < P < 4,2
Light rain	4,2 < P < 8,4
Moderate rain	8,4 < P < 18,6
Heavy rain	18,6 < P < 55,3
Very heavy rain	P > 55,3

Source: SOUZA; AZEVEDO; ARAÚJO, 2012.

Freeze and Cherry (1979) discuss that, normally: 95% of rainwater is converted into groundwater due to the difficulty in transport between soil grains; 3.5% is reverted to surface runoff; and 1.5% undergoes adsorption with the soil. These water-filled spaces in the soil are called the saturated and unsaturated portions. About water and surface runoff:

> The conclusion of most recent field studies is that overland flow is a relatively rare occurrence in time and space, especially in humid, vegetated basins. Most overlandflow hydrographs originate from small portions of the watershed that constitute no more than 10 %, and often as little as 1-3 %, of the basin area, and even on these restricted areas only 10-30 % of the rainfalls cause overland flow superficial (FREEZE; CHERRY, 1979, p. 219).

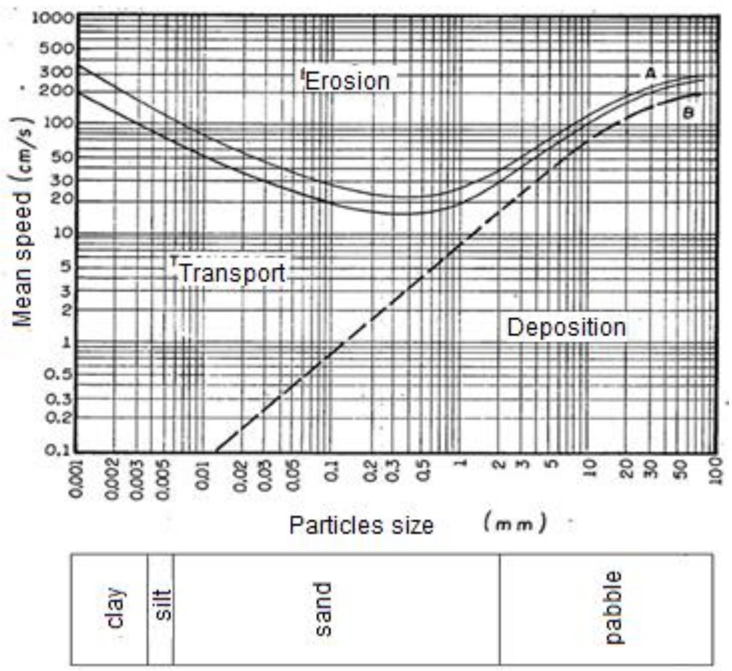
The number of consecutive days with rain, in addition to its intensity, is a determining factor for the occurrence of pluvial and flash floods (TUCCI, 2001, BRASIL, 2007, BUFFON; SOUSA, 2018):

> The CWD (Consecutive wet days) index can be useful to identify areas subject to gradual flooding. When this index is low (values around 7 days) and coincides with high extreme indexes such as Rx5day (Maximum 5-days precipitation), it can indicate that extreme precipitation phenomena occur in a short period of time, facilitating the triggering of landslides and sudden floods (MARENGO et al., 2021, p. 4).

Sand or larger soil grains enable greater infiltration, while silt and clay provide surface runoff (TUCCI, 2001). Finer soils, with the exception of clayey ones, given their cohesion, are easier transported compared to larger grains. Pebbles are more stable to erosion and need more energy to be moved. Places as hydrographic basins with soils that enable greater infiltration have less surface runoff. The soil type of the basins can also indicate where occurs greater impact of flash floods (Figure 2) considering the energy for movement (WENTWORTH, 1922, CHRISTOFOLETTI, 1981).

ISSN 1980-0827 – Volume 17, número 2, 2021

Figure 2 – Granulometry e water action.



Source: WENTWORTH (1922), CHRISTOFOLETTI (1981).
Label: A – erosion resistance; B – necessary energy to movement.

Hydrographic basins with more than 500 m² are mainly affected by the encounter of air masses, while those with a smaller area are impacted by convective rains. Due to the spatial extent, water runoff is more intense in small basins (TUCCI, 2001). Freeze and Cherry (1979) suggest that, in these spaces, not all precipitation is related to all flow. For these authors, there are areas of partial contribution within the same basin.

Monteiro and Mendonça (2011) comment that these disasters occur on slopes with 14 to 27 degrees. The water moves faster and with more energy when the height variation is much greater than the width of the transport system and it provides flash floods (TUCCI, 2001; BRASIL, 2007; MARENGO et al., 2021). These disasters cause physical damage (lives, injuries and goods) and economic damage (cost of goods and services) (MONTEIRO; MENDONÇA, 2011; BARI; ALAM; ALAM; RAHMAN; PEREIRA, 2021).

For Christofoletti (1981) it is possible to infer the impact zone of a flood through: (1) floodplain relief; (2) type of continuous established vegetation (KONDOLF; PIÉGAY, 2003); (3) relationship between channel width and depth; (4) slope of the margins; (5) FRI {(flood recurrence interval) = (Number of events +1) / (Order of magnitude of the event [ordered from largest to smallest])} with a value above 1,58. Extreme events tend to be rarer through study of FRI. As stated, flash floods are the rapid and high-energy movement of water in a given location, which possibly associated with rainfall.

3.2 Risk disaster management related to climate changes

The climate is formed by aspects of the surface and the atmosphere, and natural risks disasters associated with climate change can be studied in time and space scales (MENDONÇA, 2010). "By climate change we mean a series of changes in the Earth's climate

ISSN 1980-0827 – Volume 17, número 2, 2021

that significantly impact ecosystems, life in general and human life in particular" (FOLADORE; PIERRI, 2005, p. 17, our translation). Climate variations and changes are generally perceived when cause damage, as rising sea levels, reduction of cultivated areas (FOLADORE; PIERRI, 2005), increased temperature, heavy rains and dry periods (MONTEIRO; MENDONÇA, 2011). The accumulation of greenhouse gases resulting from fires and pollution has intensified global warming (FOLADORE; PIERRI, 2005, ZHANG et al., 2019). In addition, inadequate building has replaced the elements that maintained these cycles of energy and matter (GOUDARD; MENDONÇA, 2020).

The Sendai Framework for Disaster Risk Reduction 2015-2030 (PREVENTIONWEB, 2015, NOBRE; MARENGO, 2017), established the 7 global goals for disaster and risk management as reduction of (a) mortality, (b) affected people, (c) economic losses and (d) damage to essential services; and increase of (e) number of countries with disaster risk management, (f) international alliances for support, and (g) accessible alerts. The 4 actions to achieve these goals are: (1) disaster risk surveys; (2) articulated governance; (3) investment in resilience and (4) effective remediation. About the "accessible alerts", Buffon and Sousa (2018) and Mendonça and Buffon (2019) cite the existence of the Paraná Environmental Technology and Monitoring System (Simepar) on the State of Paraná and the National Center of Monitoring and Alerting of Natural Disasters (CEMADEN) on all Brazil territory. These alerts sends SMS (Short Message Service or cell messages) with free cost of advice inhabitants of areas at risk of imminent disasters and monitoring of meteorological websites as National Institute of Meteorology (INMET). It is possible to check the records of disaster occurrences on Brazil prepared by the Civil Defense on the S2ID platform. For flash floods, for example, the platform presents local and damage (Figures 3, 4 and 5) (BRASIL, 2021).

Figure 3 – Localization of flash flood in Civil Defense's report.

SISTEMA NACIONAL DE PROTEÇÃO E DEFESA CIVIL - SINPDEC

Formulário de Informações do Desastre - FIDE

1. IDENTIFICAÇÃO

UF: PR	Município: Morretes		Código IBGE: 4116208
População (habitantes)	PIB (Anual)	Orçamento (anual)	Arrecadação (anual)
15718	132.643,00	29.604.000,00	1.132.618,29
Receita corrente líquida (mensal)		Receita corrente líquida (anual)	
2.194.477,79		26.333.733,51	

PROTOCOLO Nº PR-F-4116208-12200-20151227

2. TIPIFICAÇÃO / 3. DATA DA OCORRÊNCIA DO DESASTRE

COBRADE	Denominação(Tipo ou Subtipo)	Dia	Mês	Ano	Horário
12200	Enxurradas	27	12	2015	18:30

4.3 Descrição das áreas afetadas

Area Rurais: Mundo Novo do Saquarema,Passa Sete,Rio Sagrado,Estrada das Canavieiras,Capituva ,Comunidade da America de Cima.
Área Urbanas: Barro Branco e Centro Historico

5. CAUSAS E EFEITOS DO DESASTRE

123 milímetros de chuvas em 48 horas de acordo com o SIMEPAR/PR,ocasionando enxurradas ,deslizamentos e alagamentos.

Source: BRASIL (2021).
Label: Black – city; Yellow – impacted places; Green – causes.

Periódico Eletrônico
Fórum Ambiental da Alta Paulista
ISSN 1980-0827 – Volume 17, número 2, 2021

Figure 4 – Physical damage of flash flood in Civil Defense's report.

6. DANOS HUMANOS, MATERIAIS OU AMBIENTAIS

6.1 DANOS HUMANOS	Discriminação		Quantidade
pelo desastre, desde	Desalojados	Pessoas que, em decorrência dos efeitos diretos do desastre, desocuparam seus domicílios, mas não necessitam de abrigo público.	20
ou cujos bens materiais tenham sido	Outros afetados	Pessoas afetadas diretamente pelo desastre (excetuando as já informadas acima)	180
danificados/destruídos.	TOTAL DE AFETADOS		**200**

6.1.1 Descrição

OUTROS: Prejudicadas pela falta de abastecimento de água potável,e pelas condições de varias estradas e pontes danificadas ,principalmente na estrada do capituva,pois ficaram sem acesso com o deslizamento do morro. DESALOJADOS: Foram 5 residencias afetadas pelo alagamento sendo 20 pessoas atingidas sem danos materiais,só bens de consumo e roupas e utensílios domésticos. em virtude das inundações do rio. Moradores retornaram as suas residencias apos o evento das águas do rio voltarem ao normal.

6.2 DANOS MATERIAIS	Discriminação	Quantidades danificadas	Quantidades destruídas	Valor (R$)
desastre.	Obras de infraestrutura pública	6	2	7.821.210

6.2.1 Descrição

DESLIZAMENTO DA ESTRADA DO CAPITUVA,PONTE MOLHADA DO RIO MARUMBI COM DESALINHAMENTO ROLAMENTO E OBSTRUÇÃO POR MATÉRIAS CARREGADOS PELA NATUREZA.PONTE PÊNSIL ,CARREGADA E DESTRUÍDA INTEGRALMENTE PELO VOLUME E EVASÃO DA ÁGUA. EROSÃO DA ESTRADA DO MOREIRA NA ESTRADA MARGINAL DA BR 277 SENTIDO RIO SAGRADO CANDONGA PONTE DE MADEIRA DA LOCALIDADE DO CANAVIEIRA,ESTRUTURA DE ACESSO DANIFICADO NA CABECEIRAS DA PONTE. BUEIRO DO SAQUAREMA,PELO VOLUME DE EVASÃO DA ÁGUA PROVOCOU DESALINHAMENTO E QUEBRA DOS TUBOS. DRENAGENS DAS ÁGUAS PLUVIAIS LOCALIZADAS NO CENTRO HISTÓRICO E BARRO BRANCO,SISTEMA DE DRENAGEM COMPROMETIDAS. ESTRADAS RURAIS E URBANAS: 162 KM FORAM EXTREMAMENTE PREJUDICADAS: SENDO ESTRADAS RURAIS 20 UNIDADES PERFAZENDO 130 KM . ESTRADAS URBANAS:65 UNIDADES PERFAZENDO 32 KM . ESTRADAS UTILIZADAS PARA TRANSPORTE DE PRODUTOS HORTIFRUTIGRANJEIROS DE ACESSO AOS MORADORES DA COMUNIDADES LINDEIRAS A ESTAS ESTRADAS COM AS FORTES CHUVAS OCASIONARAM: CORRUGAÇÕES ,ACUMULO DE MATERIAL DE ESPIGÃO,COMBINAÇÃO DO TRAFICO COM A LAVAGEM DO MATERIAL PELA ÁGUA: AREÕES DE BAIXADAS ,AREIA TRAZIDA PELAS ÁGUAS, BURACOS PLATAFORMAS MAL DRENADAS E PLANA, ACUMULO DE ÁGUA: AFLORAMENTO DE SEIXOS ROLADOS DE 100 MM A 150 MM ,EROSÃO COMBINADA COM A ÁGUA: EROSÃO EM RAVINA,SUCOS LONGITUDINAIS, SOLO DE BAIXA RESISTÊNCIA A EROSÃO DEFICIÊNCIA DE DRENAGEM E PLATAFORMA PLANA TRANSVERSAL E INCLINAÇÃO LONGITUDINAL,COMBINADO COM A ÁGUA. NECESSITANDO DE IMEDIATO DE REPAROS E RECOMPOSIÇÃO DO CONJUNTO DO GLEIDE PARA RESTABELECER COM SEGURANÇA O ACESSO TRAFEGO E ESCOAMENTO DE PRODUTOS AGRICOLAS.

Source: BRASIL (2021).
Legenda: Red – human; Black – buildings.

Figure 5 – Economic damage of flash flood in Civil Defense's report.

7. PREJUIZOS ECONOMICOS PUBLICOS E PRIVADOS

7.1 PREJUÍZOS ECONÔMICOS PÚBLICOS Informar o valor estimado de prejuízos econômicos públicos relacionados com os serviços essenciais prejudicados.	Valor total do prejuízo econômico (setor público) R$ 7.821.210,00
Serviço essencial prejudicado Serviço essencial público prejudicado ou interrompido.	**Valor do prejuízo (R$)**
Esgoto de águas pluviais e sistema de esgotos sanitários	601.880,00
Transportes locais, regionais e de longo curso	7.219.330,00

7.1.1 Descrição

PONTE PÊNSIL TOTALMENTE DESTRUÍDAS SENDO NECESSÁRIO SUA RECONSTRUÇÃO ,EXTENSÃO 25 METROS. PONTE MOLHADA COM EXTENSÃO DE 52 METROS PARCIALMENTE DANIFICADAS NECESSITANDO DE REPAROS IMEDIATOS. PONTE DE MADEIRA DO CANAVIEIRA,PARCIALMENTE DANIFICADAS. ESTRADA DO CAPITUVA:COM O EXCESSO DE CHUVAS OCASIONOU O COLAPSO EROSÃO DA PISTA DE ROLAMENTO DEVIDO O DESLIZAMENTO ,LOCAL INTERDITADO CONFORME LAUDO DA MINEROPAR/PR. EROSÃO NA ESTRADA DO MOREIRA:PRECISA DE IMEDIATO RECUPERAÇÃO . ESGOTO DE ÁGUA PLUVIAIS: BUEIRO DO MUNDO NOVO DO SAQUAREMA TOTALMENTE DESTRUÍDO DRENAGENS DxÁGUA PLUVIAIS NO CENTRO HISTÓRICO DE MORRETES E BAIRRO DO BARRO BRANCO,QUE DEVIDO AO AUTO ÍNDICE PLUVIOMÉTRICOS NÃO PODEM SER ESCOADOS . FONTE: DIRETOR DE ARQUITETURA E INFRAESTRUTURA DO MUNICÍPIO DE MORRETES PREJUÍZOS EM ÁREAS RURAIS E URBANAS: COMPROMETENDO UMA EXTENSÃO DE 160 KM DE ESTRADAS ENTRE ELAS 20 ESTRADAS RURAIS NUM TOTAL DE 130 KM E URBANAS COM 65 UNIDADES PERFAZENDO 32 KM DE ESTRADAS EM ÁREA URBANAS. ESTRADAS UTILIZADAS PARA O TRANSPORTES DE PRODUTOS HORTIFRUTIGRANJEIROS E ACESSO DOS MORADORES NAS COMUNIDADES LINDEIRAS AS ESTRADAS. PRINCIPAIS DANOS: CORRUGAÇÕES,ACUMULO DE MATERIAL DESAGREGADA PELA ÁGUA ,SEGREGAÇÃO DE AGREGADOS,DESAGREGAÇÃO DO MATERIAL PELA ÁGUA ,AREÕES DE BAIXADAS,AREIA TRAZIDA PELAS ÁGUAS DOS TRECHOS ALTOS BURACOS PLATAFORMA MAL DRENADA E PLANA,ACUMULO DE ÁGUA AFLORAMENTO DE SEIXOS ROLADOS DE 100 mm A 150 mm .EROSÃO OU CONSTANTE PATROLAMENTO COMBINADA COM A ÁGUA,NECESSITANDO DE IMEDIATO OS REPAROS E RECOMPOSIÇÃO DO GLEIDE PARA RESTABELECER COM SEGURANÇA O ACESSO,TRAFEGO E ESCOAMENTO DE PRODUTOS AGRÍCOLAS .

7.2 PREJUÍZOS ECONÔMICOS PRIVADOS Valor das perdas nos setores da agricultura, pecuária, indústria, comércio e serviços ocorridas em decorrência direta dos efeitos do desastre.	Valor total do prejuízo econômico (setor privado) R$ 650.000,00
Setores da economia	**Valor do prejuízo (R$)**
Agricultura	650.000,00

7.2.1 Descrição

PREJUDICADOS PRODUTORES RURAIS COM A FALTA DE ACESSO DA COMUNIDADE DO CAPITUVA COM O DESLIZAMENTO NÃO CONSEGUEM RETIRAR OS PRODUTOS DE SUAS SAFRAS. NÃO TEM OUTRAS ALTERNATIVAS DE ESCOAMENTO PARA RETIRAREM A SUA PRODUÇÃO. PRODUÇÃO PREJUDICADOS PELO EVENTO QUE ACONTECEU NA ESTRADA PRINCIPAL DE ACESSO DOS MORADORES E AGRICULTORES. FONTE: EMATER E CONSULTORIA AGRONÔMICA E AMBIENTAL - SECRETARIA MUNICIPAL DE AGRICULTURA DE MORRETES .LAUDOS CONFORME ANEXO NO FIDE.

Source: BRASIL (2021).
Label: Purple – Public economy; Blue – Private economy.

Although data projected by these digital platforms are accessible, Buffon and Sousa (2018) recommend comparisons between various data sources because there may be errors in their insertion in the management systems. In Brazil:

> [...] the National Plan for Adaptation to Climate Change (PNA) was launched in 2016 by the federal government, which includes a set of structuring actions for the national adaptation agenda, as well as guidelines and recommendations for 11 themes, these identified as vulnerable to climate change, including, among them, disaster risk management (NOBRE; MARENGO, 2017, p. 55, *translated*).

The National Policy on Climate Change (PNMC) (Federal Law n. 12.1873, of 2009) proposes actions at different scales. Articulated with each other to reduce the anthropogenic contribution to climate change, they conduce to mitigate and adapt to their harmful adverse effects. The National Policy for Civil Defense and Protection (PNPDEC) (Federal Law n. 12.608, of 2012) (BRASIL, 2016) is a legal policy whose function is (BRASIL, 2017, p. 39, *translated*):

> The PNPDEC must be integrated into territorial planning, urban development, health, environment, climate change, water resources management, geology, infrastructure, education, science and technology policies and other sectorial policies, with a view to promoting sustainable development, giving fundamental indications of the main policies related to Risk Management. It also establishes a systemic approach to risk management, within prevention, mitigation, preparation, response and recovery actions.

These Civil Defense actions take place at the federal, state and municipal levels. The responsibilities in relation to risk areas at the municipal level are (BRASIL, 2017):

- Identify and mapping
- Keeping the population informed about risk areas
- Develop contingency plan
- Produce simulations
- Promote inspection
- Prohibit new occupations
- Inspect
- Preventive intervention and evacuation when applicable
- Establish disaster safety in schools and hospitals located in risk areas

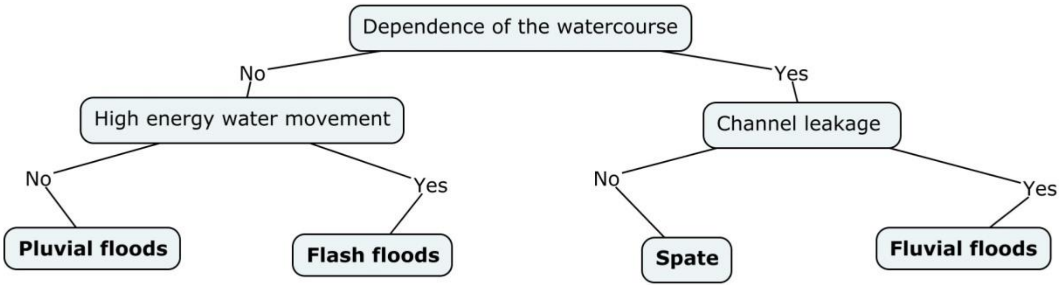
This planning was more concerned with solutions than prevention in its beginnings but it changed due given global evidence of management (SAUSEN; LACRUZ, 2015, BUFFON, 2018). Prevention and response actions are divided in structural or physical and non-structural or regulatory (BRASIL, 2007). In general, there is a proposal for actions based on a diagnosis.

3.3 Actions related to flash floods

Carlos Tucci (2001) suggests structural and non-structural actions for water disasters. Structural actions include: existence of vegetation, land cover that reduces soil loss, dykes and maintenance of water channels. Non-structural measures are: zoning of risk areas, resilient infrastructure, financial insurance after damage and monitoring (MONTEIRO; MENDONÇA, 2011).

Fluvial, pluvial and flash floods and spates are differentiated by their dependence of the watercourse (BUFFON; SOUSA, 2018), channel leakage and intensity (Figure 6) (UFSC/ CEPED, 2013, SAUSEN; LACRUZ, 2015). Reforestation is a very important and frequent action to these disasters (COHEN-SHACHAM et al., 2019). It is important to emphasize that reforestation is always preferable to be produced with native plants because they have more adaptations to the soil (SHIMAMOTO et al., 2018; GALOSKI et al., 2019).

Figure 6 – Surface hydrological disasters.



Source: BRASIL (2007).

The vegetation cover is highlighted because it offers the services: water infiltration; reduced surface runoff; habitat creation; carbon sequestration; erosion control; and temperature reduction (GRIMALDI et al., 2014; ADLER; TANNER, 2015; ROSIN; BENINI, 2018). On the other hand, deforestation and buildings facilitate the formation of heat islands, loss of biodiversity, environmental fragility for various types of weathering and surface water runoff (ADLER; TANNER, 2015). Roots and deposition of organic matter from vegetation promote soil aggregation and reduces reduce surface runoff by more diverse ecological processes with pores formation (GRIMALDI et al., 2014; GALOSKI et al., 2019). Vegetation cover has been presented as one of the main reducers of flash floods (TUCCI, 2001, GRIMALDI et al., 2014, ADLER, TANNER, 2015, NOBRE, MARENGO, 2017, ROSIN; BENINI, 2018, COHEN-SHACHAM et al. , 2019, GALOSKI et al., 2019).

The aspect of vegetation and land cover is associated with interception and infiltration of rainwater (TUCCI, 2001). Amaral, Guthahr and Ross (2021) observed that waterproofing and structural changes in water channels in river plain areas, where heavy rains occur, affect drainage. Types of land covers, as paving and deforestation, that originate waterproofing and/or reduce infiltration are among the main causes of floods. The activities illegal occupation, population densification, intense exploitation of natural assets by agriculture, livestock and mining affect the climate of a region and, therefore, water processes (SARKAR et al., 2020).

Monteiro and Mendonça (2011) and Santos and Ross, (2012) propose that the description of susceptible spatial units occurs by verifying: natural dynamics; land cover and use; and economic ecological zoning (EEZ). This quantitative data is transformed into qualitative indexes to classify the areas. Territorial planning and ecological zoning are highly suggested actions in the adoption of buildings further away from a water bodies (TUCCI, 2001, SANTOS; ROSS, 2012, AMARAL; GUTHAHR; ROSS, 2021). In Brazil, the National Water Resources Policy (PNRH) is similar to that suggested by the Forest Code, since both are in opposition to deforestation and occupation of the margins of water bodies (FREITAS, 2011).

Nobre and Marengo, (2017) comment about the need for sociological studies for disaster risk management because are less than physical studies. The Brazilian Institute of Geography and Statistics (IBGE) is one of the main sources for these researches on Brazil (BUFFON; SOUSA, 2018).

Besides land cover and other surface studies, atmospheric research is also useful in managing these risks (MENDONÇA, 2010; MONTEIRO; MENDONÇA, 2011; NEVES; MACHADO;

CAMARGO, 2017). Mendonça and Buffon (2019) related harmful hydrological events with the Tropical Atlantic Air Mass (TAAR) and Cold Fronts (CF) using data from more than one meteorological station to cover different records of flooding zones on the city of Curitiba, Paraná (BUFFON; SOUSA, 2018). Some modeling software as EDDA-Chuva (NOBRE; MARENGO, 2017) or even modeling products (INMET, 2021, WORLDCLIM, 2021) can be used to estimate rainfall. These atmospheric studies with geomorphology can demonstrate the proposition of more effective actions (MENDONÇA, 2010, MONTEIRO; MENDONÇA, 2011).

The main actions of Civil Defense with flash floods are monitoring of risk areas and response to damage. It is necessary the territorial planning with social and meteorological data to prevent these disasters.

4 CONCLUSION

The actions in Brazil for the management of the risk of hydrological disaster flash flood presented by the Civil Defense are relatively in accordance with international regulations. They include identification, monitoring and planning of risk areas and appropriate structural and non-structural responses to each event. These actions are supported by scientific research in geography, sociology, geology, meteorology and others, although greater application of these areas of knowledge is needed.

This study aimed to present what are and how to manage with flash floods, especially in Brazil. Other studies are needed to verify the practice of these actions over time in bulletins, minutes and other municipal, state and federal documents. This monitoring of Civil Defense records can indicate results on response time, equipment, technical teams, investment, etc. The suggestion for a better understanding of future scenarios of hydrological disasters is to analyze pluvial, fluvial and flash floods.

BIBLIOGRAPHICAL REFERENCES

ADLER, F. R.; TANNER, C. J. **Ecossistemas urbanos**: princípios ecológicos para o ambiente construído. São Paulo: Oficina de Textos, 2015.

ANA - Agência Nacional de Águas. **Atlas de Vulnerabilidade a Inundações**. Brasília: ANA, 2014.

AMARAL, R.; GUTHAHR, M.R.; ROSS, J.L.S. THE OCCURRENCE OF FLOODS IN SÃO PAULO, BRAZIL: THE IPIRANGA STREAM BASIN CASE STUDY**. International Journal of Water Management and Diplomacy**. v., n.2, p.5-22, 2021.

BARI, M.A.; ALAM, L.; ALAM, M.D.; RAHMAN, L.F.; PEREIRA, J.J. Estimation of losses and damages caused by flash floods in the commercial area of Kajang, Selangor, Malaysia. **Arabian Journal of Geosciences**, v.14, 195, 2021.

BORSATO, V.A.; MASSOQUIM, N. G. Os movimentos, as áreas de atuação e as propriedades das massas de ar no Brasil. **Geomae**, v.11, n.1, p.27-56, 2020.

BRASIL. Ministério das Cidades. Instituto de Pesquisas Tecnológicas. **Mapeamento de riscos em encostas e margens de rios**. Brasília: Ministério das Cidades; Instituto de Pesquisas Tecnológicas, 2007.

BRASIL. **Modelagem Climática e Vulnerabilidades Setoriais à Mudança do Clima no Brasil**. Brasília: Ministério da Ciência, Tecnologia e Inovação, 2016.

BRASIL. Ministério da Integração Nacional. Secretaria Nacional de Proteção e Defesa Civil. Departamento de Prevenção e Preparação. **Módulo de formação**: noções básicas em proteção e defesa civil e em gestão de riscos: livro base. Brasília: Ministério da Integração Nacional, 2017.

BRASIL. **S2ID - Sistema Integrado de Informações sobre Desastres**. 2021. Disponível em: https://s2idsearch.labtrans.ufsc.br/. Acesso em: 18 jun. 2021.

BUFFON, E.A.M. Vulnerabilidade socioambiental à leptospirose humana no aglomerado urbano metropolitano de Curitiba, Paraná, Brasil: proposta metodológica a partir da análise multicritério e álgebra de mapas. **Saúde e Sociedade**. São Paulo, v.27, n.2, p.588-604, 2018.

BUFFON, E.A.M.; SOUSA, M.S. Proposta metodológica para avaliação dos registros secundários de alagamentos: uma abordagem a partir de Curitiba-Paraná, Brasil. **Caminhos de Geografia Uberlândia**, v.19, n.67, p. 188–204, 2018.

CHRISTOFOLETTI, A. **Geomorfologia fluvial**. São Paulo: Edgard Blucher, 1981.

COHEN-SHACHAMA, E.; ANDRADE, A.; DALTON, J.; DUDLEY, N.; JONES, M.; KUMAR, C.; MAGINNIS, S.; MAYNARD, S.; NELSON, C.R.; RENAUD, F.G.; WELLING, R.; WALTER, G. Core principles for successfully implementing and upscaling Nature-based Solutions. **Environmental Science and Policy**, v.98, p.20-29, 2019.

FOLADORE, G.; PIERRI,N. (Orgs). **Sustentabilidad?** Desacuerdos sobre el desarollo suetentable. Migeul Angel Porrúa: Universidade Autônoma de Zacatecas, 2005.

FREEZE, R.A.; CHERRY, J.A. **Groundwater**. New Jersey: Prentice-Hall Inc., 1979.

FREITAS, C.M. **Um equilíbrio delicado**: crise ambiental e a saúde no planeta. Rio de Janeiro: Garamond, 2011.

PINHEIRO, L.S.; GORAYEB, A. (Orgs.). **Geografia Física e as Mudanças Globais**. Fortaleza: Editora UFC, 2019.

GADDA, T.M.C.; VELLOZO, L.D.; STÖBERL, A.P.M.; DIAZ, L.T. Trajetória do conceito soluções baseadas na natureza e a relação com o Brasil: Uma análise bibliográfica. In: SANTOS, F. (Org.). **Geografia no Século XXI** - Volume 5. Belo Horizonte: Editora Poisson, 2019, p.61-72.

GALOSKI, C.E.; MARTINEZ, A.E.; SCHULTZ, G.B.; SANTOS, I.; FROEHNER, S. Use of n-alkanes to trace erosion and main sources of sediments in a watershed in southern Brazil. **Science of the Total Environment**, v. 682, p. 477-456, 2019.

GOUDARD, G.; MENDONÇA, F.A. Eventos e episódios pluviais extremos: a configuração de riscos hidrometeorológicos em Curitiba (Paraná - Brasil). **IdeAs**, v. 15, p. 1-17, 2020.

GRIMALDI, M.; OSZWALD, J.; DOLÉDEC, S.; HURTADO, M.; MIRANDA, I.; SARTRE, X. A.; ASSIS, W. S.; CASTAÑEDA, E.; DESJARDINS, T.; DUBS, F.; GUEVARA, E.; GOND, V.; LIMA, T. T. S.; MARICHAL, R.; FERNANDO, M.; MITJA, D.; NORONHA, N.C.; OLIVEIRA, M.N.D.; RAMIREZ, B.; RODRIGUEZ, G.; SARRAZIN, M.; JUNIOR, M. L. S.; COSTA, L. G. S.; SOUZA, S. L.; VEIGA, I.; VELASQUEZ, E.; LAVELLE, P. Ecosystem services of regulation and support in Amazonian pioneer fronts?: searching for landscape drivers. **Landscape Ecology**, v. 29, p. 311–328, 2014.

GUERRA, A.; REIS, L.K.; BORGES, F.L.G.; OJEDA, P.T.A.; ARMANDO, D.; PINEDA, M.; MIRANDA, C.O.; MAIDANA, D.P.F.L.; SANTOS, T.M.R.; SHIBUYA, P.S.; MARQUES, M.C.M.; LAURANCE, S.G.W.; GARCIA, L.C. Ecological restoration in Brazilian biomes: Identifying advances and gaps. **Forest Ecology and Management**, v.458, 117802, 2020.

INMET - Instituto Nacional de Meteorologia. **Prognóstico de Precipitação**. 2021. Disponível em: https://clima.inmet.gov.br/progp/0. Acesso em: 12.5.2021.

KONDOLF G.M.; PIÉGAY, H. (Eds). **Tools in Fluvial Geomorphology**. Chichester, John Wiley & Sons, 2003.

MARENGO, J.A.; CAMARINHA, P.I.; ALVES, L.M.; DINIZ, F.; BETTS, R.A. Extreme Rainfall and Hydro-Geo-Meteorological Disaster Risk in 1.5, 2.0, and 4.0◦C Global Warming Scenarios: An Analysis for Brazil. **Frontiers in Climate**, v.3, 610433, 2021.

MONTEIRO, C.A.F.; MENDONÇA, F.A. (Orgs). **Clima urbano**. 2 ed. São Paulo: Contexto, 2011.

MENDONÇA, F.A. RISCOS E VULNERABILIDADES SOCIOAMBIENTAIS URBANOS a contingência climática. **Mercator**, v.9, n.1, p.153-163, 2010.

MENDONÇA, F. (Org). **Os Climas do Sul**: Em Tempos de Mudanças Climáticas Globais. Jundiaí: Paco Editorial, 2017.

MENDONÇA, F.A.; BUFFON, E.A.M. APLICAÇÃO DA ESCALA TEMPORO-ESPACIAL FINA EM ESTUDO DE INUNDAÇÕES URBANAS: PAINÉIS PARA CURITIBA-PR, BRASIL. **Geo UERJ**, n. 34, e, 40943, 2019.

NEVES, C.E.; MACHADO, G.; CAMARGO, K.C. Subsídio do sistema GTP (Geossistema- Território-Paisagem) na percepção de riscos ambientais: esboço metodológico. **Geografia**, v.26, n.1, p.76–91, 2017.

NOBRE, C.A.; MARENGO, J.A. (Orgs). **Mudanças climáticas em rede**: um olhar interdisciplinar. São José dos Campos: INCT, 2017.

PINHEIRO, L.S.; GORAYEB, A.. (Org.). **Geografia Física e as Mudanças Globais**. Fortaleza: Editora UFC, 2019.

PREVENTIONWEB. **Sendai Framework for Disaster Risk Reduction 2015-2030**. 2015. Disponível em: https://www.preventionweb.net/publications/view/43291. Acesso em: 11 jun. 2021.

ROSIN, J.A.R.G.; BENINI, S.M. (org). **Cidade sustentável**: um conceito em construção. Tupã: Associação Amigos da Natureza da Alta Paulista, 2018.

SANTOS, J.O.; ROSS, J.L.S. FRAGILIDADE AMBIENTAL URBANA. **Revista da ANPEGE**, v. 8, p. 127-144, 2012.

SARKAR, P., SALAMI, M., GITHIORA, Y., VIEIRA, R., NAVARRO, A., CLAVIJO, D., PADGURSCHI, M. A conceptual model to understand the drivers of change in tropical wetlands: a comparative assessment in India and Brazil. **Biota Neotropica,** 20(suppl. 1): e20190913, 2020.

SAUSEN, T.M.; LACRUZ, M.S.P. **Sensoriamento Remoto para desastres**. São Paulo: Oficina de Textos, 2015.

SHIMAMOTO, C.Y., PADIAL, A.A., ROSA, C.M., MARQUES, M.C.M. Restoration of ecosystem services in tropical forests: A global meta-analysis. **PLoS ONE**, v.13, n.12, e0208523, 2018.

SOUZA, W.M.; AZEVEDO, P.V.; ARAÚJO, L.E. Classificação da precipitação diária e impactos decorrentes dos desastres associados às chuvas na cidade do Recife-PE. **Revista Brasileira de Geografia Física**, v.5, n.2, p.250-268, 2012.

TUCCI, C.E.M. **Hidrologia**: ciência e aplicação. 2 ed. Porto Alegre: UFRGS, 2001.

UFSC - Universidade Federal de Santa Catarina. CEPED - Centro Universitário de Estudos e Pesquisas sobre Desastres. **Atlas Brasileiro de Desastres Naturais**: 1991 a 2012. 2. ed. Florianópolis: CEPED UFSC, 2013.

WENTWORTH, K. A Scale of Grade and Class Terms for Clastic Sediments**. Journal of Geology**, v.30, n.5, p. 377-392, 1922.

WOHLLEBEN, P. **THE HIDDEN LIFE OF TREES**: The Illustrated Edition. Vancouver: Greystone Books, 2018.

WORLDCLIM. **Future climate, 2.5 minutes spatial resolution**. 2021. Disponível em: https://www.worldclim.org/data/cmip6/cmip6_clim2.5m.html. Acesso em: 08.6.2021.

ZHANG, Y.; WANG, Y.; CHEN, Y.; LIANG, F.; LIU, H. Assessment of future flash flood inundations in coastal regions under climate change scenarios—A case study of Hadahe River basin in northeastern China. **Science of the Total Environment**, v.693, p.133550-133550, 2019.