MAPBIOMAS

Climatic Risk “Handbook”

Algorithm Theoretical Basis Document (ATBD)

Collection 1

Version 1

November, 2025

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Introduction

This report documents the Algorithm Theoretical Basis (ATBD) for Collection 1 of the MapBiomas Climatic Risk product. This collection provides a historical analysis of susceptibility to climate-related hazards in Brazil. This BETA version does not include the rainfall trigger analysis that will be integrated to

This methodology is built using several key inputs, including land use and cover data from MapBiomas Land Use/Cover Collection 10.

Collection 1 is composed of three primary datasets, each detailed in this document:

1. **Urban Areas Susceptible to Landslides:** A historical time series (1985–2023) of landslide susceptibility in urban areas, based on geomorphological and land use factors.
2. **Urban Areas Susceptible to Flooding:** An analysis of urban areas prone to flooding, inundation, or flash floods, based on topographic and hydrological models.
3. **Water Security Index (ISH) Integration:** A layer integrating data from the National Water Agency (ANA) to identify areas where high physical risk intersects with systemic water security vulnerability.

Urban areas susceptible to landslides

1. Introduction

This report documents the methodology used to create a historical map of landslide susceptibility in urban areas of Brazil. The workflow integrates geoscientific datasets, topographic indices, and land use data, applying spatial logic and connected component analysis to produce annual susceptibility assessments from 1985 to 2024. The methodology is based on the adapted scientific model by Camarinha et al. (2020), extended with additional geomorphological and urban datasets.

Natural susceptibility refers to the inherent potential for the spatial occurrence for geomorphological and geological processes, such as erosion, mass movements and floods, determined by a set of conditioning factors, such as slope morphology, soil characteristics, lithology, water dynamics, and land use (Fernandes et al., 2001; Corominas et al., 2014). Thus, it should not be regarded as a synonym with risk zonation that will be implemented in the next version.

2. Datasets Used

- Lithostratigraphy: Serviço Geológico Brasileiro (SGB) 1:2,500,000

- Pedology: IBGE 1:250,000

- Elevation: NASADEM_HGT/001 (30m resolution)

- Land Use/Cover: MapBiomas Collection 10

- Buildings: Google Open Buildings Temporal v1

- Geological risk areas: Serviço Geológico Brasileiro (SGB)

3. Methodological Steps

Step 1: Base Susceptibility Modeling

Based on the work of Camarinha et al. (2020), the initial model integrates five variables: 1) lithostratigraphy, 2) pedology, 3) terrain slope and 4) curvature, and 5) land use/cover (MapBiomas Collection 10). Each variable was reclassified into susceptibility weights ranging from 0 to 1. The final susceptibility score is the simple average of the five inputs, followed by a reclassification into three categories: Medium (0.5–0.55), High (0.55–0.6), and Very High (> 0.6).

Step 2: Topographic Index Derivation

Terrain derivatives and morphometric indices were calculated from NASADEM elevation data, following Amatulli et al. (2020), which uses a 3x3 pixel kernel for geomorphometric indexes . Derived bands include slope, aspect, plan and profile curvature, topographic wetness index (TWI), stream power index (SPI), roughness, Topographic Rudgeness Index (TRI), Vector Rudgeness Measure(VRM), and Topographic Position Index (TPI). These indices informed spatial filtering rules and were exported as a multi-band image.

Step 3: Spatial Filtering and Component Analysis

The base susceptibility was refined by applying three filters: (i) exclusion of ridgelines using TPI > 2, (ii) exclusion of very smooth terrain (roughness < 10), and (iii) connected pixel filtering, keeping only susceptibility patches larger than 5 connected pixels (~ 0.5 ha) These refinements improved spatial consistency.

Step 4: Urban Filtering and Historical Time Series

Each susceptibility component was intersected with urban areas from MapBiomas Collection 10 (1985–2024) and Google Open Buildings (2016–2024). Only components touching urban pixels were retained, resulting in a time series of annual urban landslide susceptibility maps. These were stacked into a multi-band image asset with metadata for public use.

4. Integration Logic and Rules

The final susceptibility classification applied the following logic:

- Remove slopes < 8°, curvature < 200, roughness < 10, and TPI > 2
- Remove components smaller than ~0.5 ha (5 pixels)
- Reclassification thresholds: Medium = 0.5–0.55, High = 0.55–0.6, Very High > 0.6
- Urban intersection using buffer of 1 pixel

5. Integration with SGB Geological Risk Areas

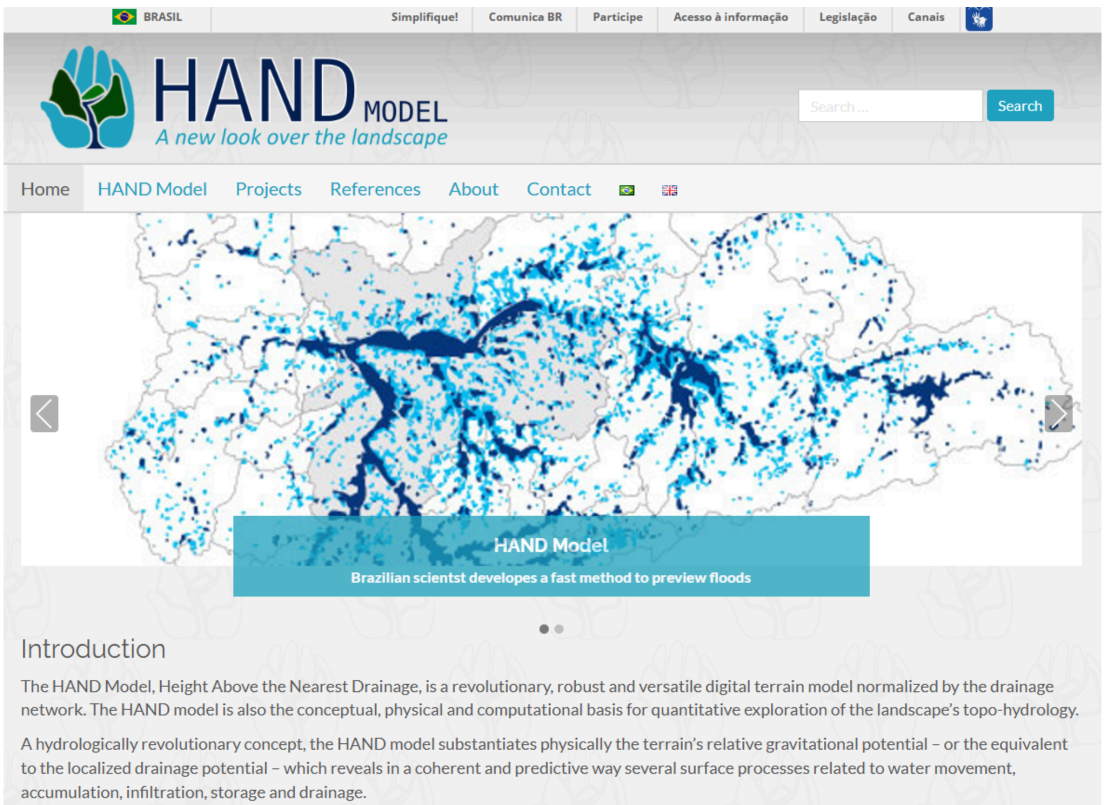
The final product incorporates official geospatial data from the *Serviço Geológico Brasileiro* (SGB). These layers include polygons mapped as being at risk of landslides, mass flows and collapses. These polygons are flagged as 'very high' susceptible areas.

Urban areas susceptible to flooding, inundation or flash floods

An additional susceptibility layer was developed to identify urban areas susceptible to flooding, inundation, or flash floods. This product combines two key datasets: the HAND (Height Above Nearest Drainage) model and the JRC Global River Flood Hazard map.

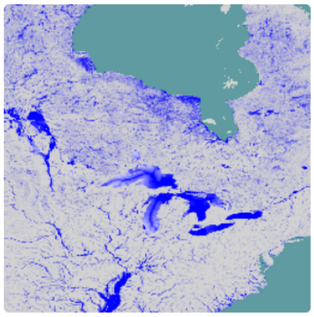
1. Datasets Used

- HAND (Height Above Nearest Drainage) from INPE: https://handmodel.ccst.inpe.br



- Global River Flood Hazard (JRC, 100-year return period):

JRC Global River Flood Hazard Maps Version 2.1



Dataset Availability

2024-03-16T00:00:00 - 2024-03-16T23:59:59

Dataset Provider

Joint Research Centre

Collection Snippet

```
ee.ImageCollection("JRC/CEMS_GLOFAS/FloodHazard/v2_1")
```

See example

Tags

flood monitoring wri

DESCRIPTION BANDS IMAGE PROPERTIES TERMS OF USE CITATIONS DOIS

The global river flood hazard maps are a gridded data set representing inundation along the river network, for seven different flood return periods (from 1-in-10-years to 1-in-500-years). The input river flow data for the new maps are produced by means of the open-source hydrological model LISFLOOD, while inundation simulations are performed with the hydrodynamic model LISFLOOD-FP. The extent comprises the entire world with the exception of Greenland and Antarctica and small islands with river basins smaller than 500 km^2.

Cell values indicate water depth (in meters). The maps can be used to assess the exposure of population and economic assets to river floods, and to perform flood risk assessments. The dataset is created as part of the Copernicus Emergency Management Service.

This version also includes additional datasets. For each tile, a flood hazard map is available with water depth categorized according to the GloFAS "Flood hazard 100 year return period" static layer. Furthermore, the "spurious_depth_category" band identifies areas where depths greater than 10m are predicted in small channels (less than 3,000km^2) for the 10-year return period, including a 2km buffer.

Note: The band structure has been updated in this version (v2). Each return period now has separate bands for depth and depth category. Additionally, bands for permanent water class and spurious depth category are included.

Geological risk areas provided by the Serviço Geológico Brasileiro (SGB)

https://www.sgb.gov.br/cartografia-de-riscos-geologicos

gov.br | Ministério de Minas e Energia

SGB

Serviço Geológico do Brasil

Prevenção de Desastres

Geocientífico > Prevenção de Desastres > Cartografia de Riscos Geológicos

Cartografia de Risco Geológico

A Cartografia de Áreas de Risco Geológico consiste na identificação e caracterização das porções do território municipal sujeitas a sofrerem perdas ou danos causados por eventos adversos de natureza geológica. Este estudo é elaborado em consonância co[m] as diretrizes e objetivos estabelecidos pela Política Nacional de Proteção e Defesa Civil, instituída pela Lei 12.608/2012, e obje[...] subsidiar a tomada de decisões assertivas relacionadas às políticas de ordenamento territorial e prevenção de desastres.

2. Methodology

The HAND raster provides elevation above local drainage networks. A pixel is classified as flood-prone based on its HAND value:
- HAND 0–2 meters → Very High Susceptibility
- HAND 2–4 meters → High Susceptibility
- HAND 4–6 meters → Medium Susceptibility

These classes are masked to retain only areas overlapping with the JRC Global River Flood Hazard map (return period = 100 years). This ensures the model captures both topographic vulnerability and hydrological risk.

The resulting map highlights urban pixels (based on MapBiomas Collection 10 1985-2024) that intersected HAND-derived flood zones and the global flood hazard layer. This product complements the landslide susceptibility analysis by capturing pluvial and fluvial flood risks in urban areas.

3. Integration with SGB Geological Risk Areas

To enhance the spatial accuracy and national coverage of flood-related hazards, the final product incorporates official geospatial data from the *Serviço Geológico Brasileiro* (SGB). These layers include polygons mapped as being at risk of flooding, flash floods, riverine inundation, and other water-related events.

The areas delineated by SGB are used to reinforce or complement the HAND and JRC-based susceptibility map. When any of these SGB polygons intersect urban areas identified as potentially flood-prone, the region is flagged as 'very high' for combined hydro-geological risk monitoring.

Water Security Index (ISH)

The final integrated climate risk assessment incorporates the Water Security Index (ISH – *Índice de Segurança Hídrica*), a composite indicator developed by the Brazilian National Water Agency (ANA). The ISH reflects dimensions such as:

- Water availability
- Infrastructure and supply capacity
- Socioeconomic demand pressure
- Environmental and climate vulnerabilities

This index allows the identification of regions with structural weaknesses in water security. In the current methodology, areas with low ISH values were flagged as more vulnerable, especially when intersecting with zones of high susceptibility to landslides or flooding.

The dataset is accessible through the SNIRH metadata platform:

https://metadados.snirh.gov.br/geonetwork/srv/api/records/c349dc5a-0c01-4f14-9519-e3340fef2c66

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- Camarinha, P.I.M., Canavesi, V., & Alvalá, R.C.S. (2014). Shallow landslide prediction and analysis with risk assessment using a spatial model in a coastal region in São Paulo, Brazil. https://doi.org/10.5194/nhess-14-2449-2014

- COROMINAS, J., VAN WESTEN, C., FRATTINI, P. et al. Recommendations for the quantitative analysis of landslide risk. Bull Eng Geol Environ 73, 209–263. 2014. DOI: https://doi.org/10.1007/s10064-013-0538-8

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- MapBiomas Project – Collection 10 of Brazilian Land Cover & Use Map Series (1985–2023), Google Earth Engine.

- Google Research – Open Buildings Temporal Dataset (2016–2023).

- Serviço Geológico do Brasil (SGB) – Official Risk Cartography. https://www.sgb.gov.br/cartografia-de-riscos-geologicos

- HAND Model – INPE. https://handmodel.ccst.inpe.br

- JRC Global River Flood Hazard Map (100-year RP). https://data.jrc.ec.europa.eu/dataset/jrc-floods-floodmapgl_rp100y-tif

- Agência Nacional de Águas e Saneamento Básico (ANA) – Índice de Segurança Hídrica (ISH). https://metadados.snirh.gov.br/geonetwork/srv/api/records/c349dc5a-0c01-4f14-9519-e3340fef2c66

Appendix: Reclassification Tables by Theme for susceptible to landslides

Pedology (Soil Types)

Argissolo	0.0
Cambissolo	0.8
Chernossolo	0.0
Corpo d'água	0.0
Dunas	0.0
Espodossolo	0.55
Gleissolo	0.6
Latossolo	0.8
Luvissolo	0.0
Neossolo	0.6
Nitossolo	0.6
Organossolo	0.0
Outros	0.0
Planossolo	0.0
Plintossolo	0.0
Vertissolo	0.0

Lithology (Rock Types)

Metamorphic, Igneous	0.43
Igneous	0.5
Metamorphic	0.77
Superficial Material	1.0
Superficial + Igneous	1.0
Superficial + Sedimentary	1.0
Metamorphic + Undefined + Sedimentary	1.0
Metamorphic + Sedimentary	1.0
Metamorphic + Sedimentary + Igneous	1.0
Undefined + Sedimentary	1.0
Sedimentary	1.0
Sedimentary + Igneous	1.0

Land Use and Cover (MapBiomas)

3	Forest Formation	0.4
4	Savanna Formation	0.4
5	Mangrove	0.2
49	Wooded Sandbank Vegetation	0.5
11	Wetland	0.4
12	Grassland	0.4
32	Hypersaline Tidal Flat	0.4
29	Rocky Outcrop	0.4
50	Herbaceous Sandbank Vegetation	0.5
15	Pasture	0.7
19	Temporary Crop	0.8
39	Soybean	0.8
20	Sugarcane	0.8
40	Rice	0.8
62	Cotton (beta)	0.8
41	Other Temporary Crops	0.8
46	Coffee	0.8
47	Citrus	0.8
35	Palm Oil	0.8
48	Other Perennial Crops	0.8
9	Forest Plantation	0.7
21	Mosaic of Uses	0.7
24	Urban Area	1
30	Mining	0.9
25	Other Non-Vegetated Areas	0.9

Slope (degrees)

< 8	0.0
8 – 20	0.5
20 – 45	0.8
> 45	1.0

Curvature (Profile/Plan)

≤ 200	0.0
201–350	0.2
351–500	0.5
501–700	0.8
> 700	1.0