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Mortality associated to Hydro-Geomorphologic Disasters in the Great Lisbon area in the last 150 years

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OUTLINE

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2. OBJECTIVES

(i) the spatio-temporal analysis of hydro-geomorphological disasters occurred in the last 150 years of the Great Lisbon area;

(ii) the analysis of the frequency and the temporal evolution of fatal floods and landslides;

(iii) the analysis of the spatio-temporal distribution of fatalities;

(iv) the verification of gender tendencies in mortalities; and

(v) the evaluation of individual and societal risk.

Great Lisbon Area represents 47% of the national mortality associated with HG disasters (Pereira et al. 2015) including 21.2% of the Portuguese population and four of the most densely populated municipalities of the country (Lisbon, Sintra, Cascais, Loures).

2. DATA AND METHODS

In Portugal, social impacts (fatalities, injuries, missing people, evacuated and homeless people) caused by floods and landslides in the last 150 years are gathered in the DISASTER database (Zêzere et al. 2014) during the period of 1865–2010. This database is the only database containing detailed data on the social impacts of HG disasters in Portugal.

A set of national and regional newspapers were used in the data-collection process from which DISASTER cases were identified.

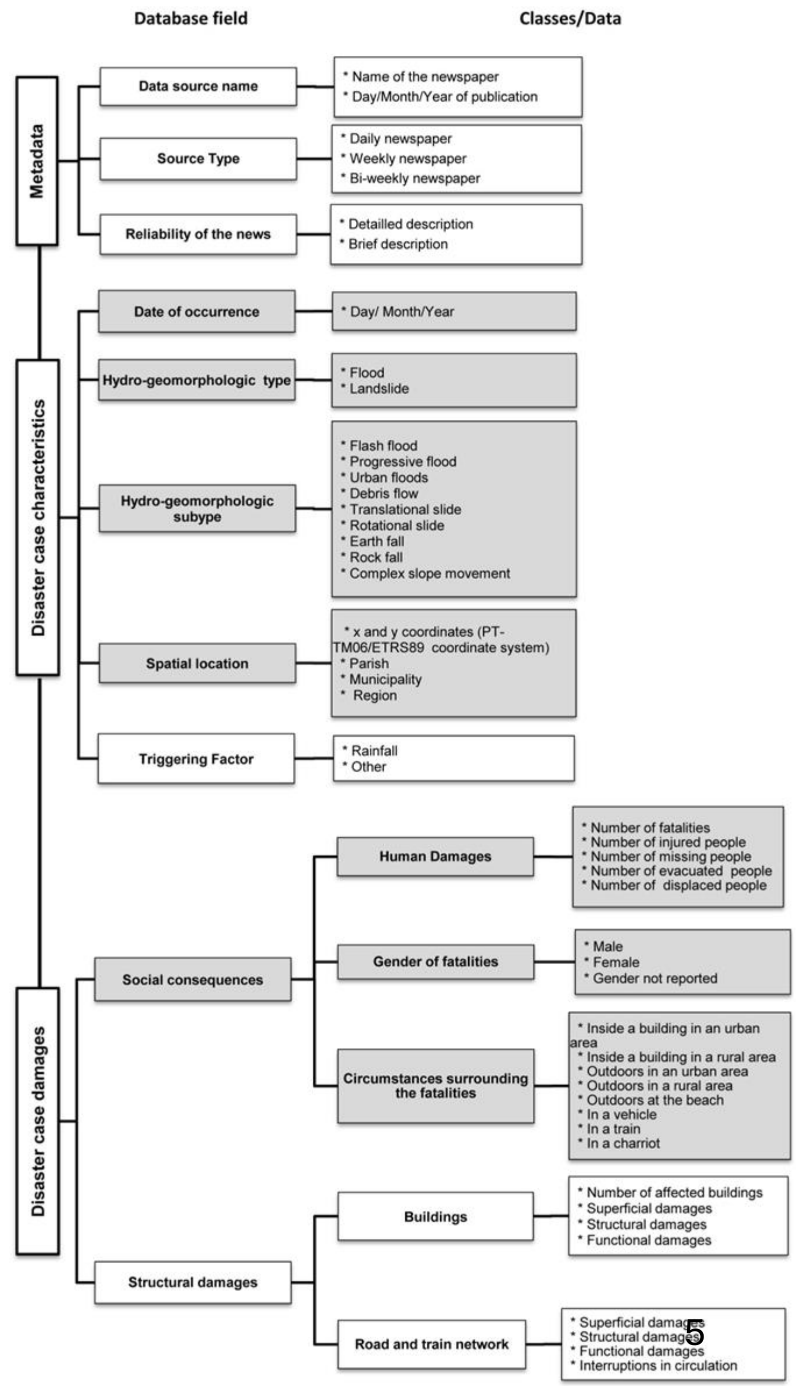
DISASTER case - is a unique HG occurrence, which fulfills the DISASTER database criteria (i.e., any flood or landslide that, independently of the number of affected people, caused casualties, injuries, or missing, evacuated, or homeless people), and is related to a unique geographic location and a specific period of time (i.e., the specific place and time where the harmful consequences of the flood or landslide occurred) (Zêzere et al. 2014).

2. DATA AND METHODS

A content analysis of the newspapers reports of DISASTER cases was made in order to organize the information in a standardized format.

Each DISASTER case includes details on the disaster characteristics and damages. The first includes data on type (flood or landslide), subtype, date of occurrence, location, and triggering factor (Zêzere et al. 2014).

The second includes structural damages (damage to buildings and damages to train and road networks) and social consequences (human damage, gender of fatalities, and circumstances surrounding the fatalities).



2. DATA AND METHODS

Individual risk was evaluated using mortality rates for floods and landslides, which were calculated based on years with population census in Portugal, i.e., normally every 10 years. Fortunately, the first modern population census in Portugal dates from 1864.

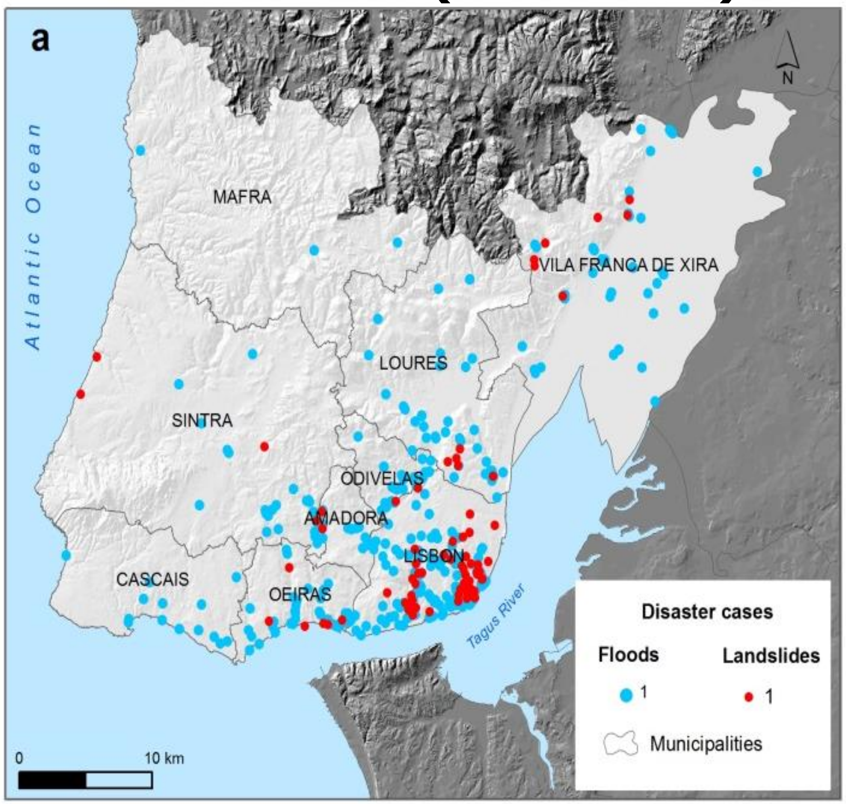
The **annual mortality rates** were computed for each decade using the annual average of fatalities, which were then divided by the annual average population. The result was multiplied per 100,000 to scale it according to the size of population per unit time (Pereira et al. 2015).

Societal risk was evaluated by plotting F-N curves representing the annual frequency of flood and landslide cases that generated fatalities.

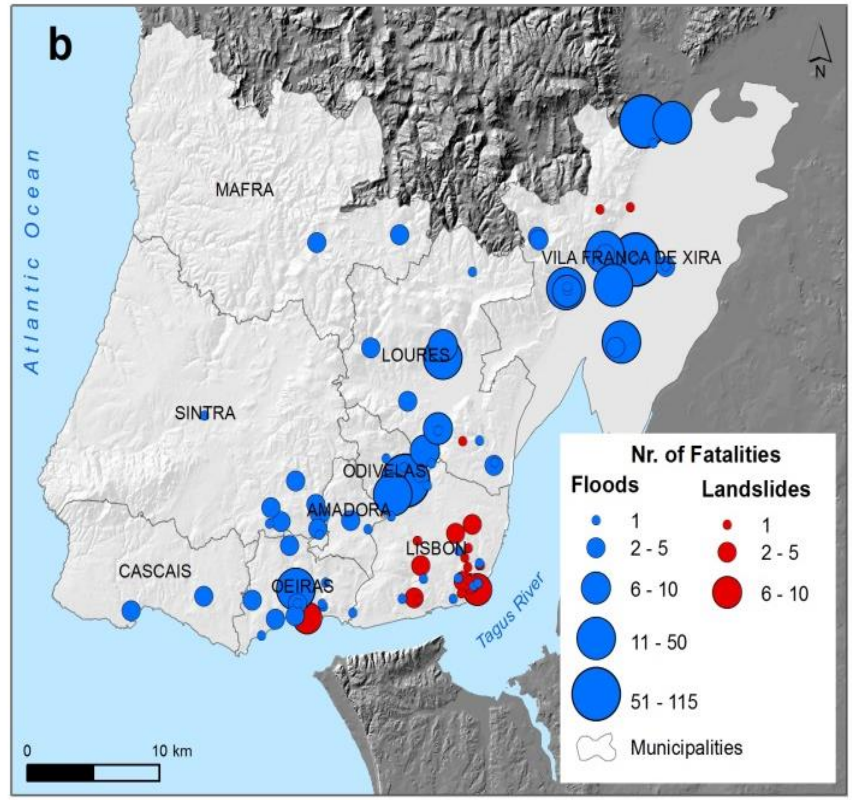
3. DATA AND METHODS

3.1 Spatial distribution of mortality

Disaster cases (1865-2010)



Disaster fatalities (1865-2010)



Landslide Disaster cases were dominant in the Lisbon municipality (68.3%) and also landslide fatalities (69.6%)

Flood fatalities were mainly located in Vila Franca de Xira, Odivelas, Loures and Oeiras municipalities.

3. DATA AND METHODS

3.1 Spatial distribution of mortality

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		Flood Disaster cases			Flood Fatalities		
Municipality	**Area (km^2)**	**Number**	**%**	**Density (#100km^2)**	**Number**	**%**	**Density (#100km^2)**
Amadora	23.8	11	3.0	0.24	6	1.1	0.06
Cascais	97.4	17	4.6	0.97	6	1.1	0.06
Lisbon	85.0	133	35.8	0.85	10	1.9	0.10
Loures	169.1	49	13.2	1.69	40	7.4	0.40
Mafra	291.7	3	0.8	2.92	6	1.1	0.06
Odivelas	26.5	31	8.4	0.27	96	17.8	0.96
Oeiras	45.9	44	11.9	0.46	39	7.2	0.39
Sintra	319.2	29	7.8	3.19	22	4.1	0.22
Vila Franca de Xira	318.1	54	14.6	3.18	313	58.2	3.13
Total	**1376.7**	**371**	**100.0**	**13.77**	**538**	**100.0**	**5.38**

Disastrous flood are mainly located in Lisbon, Loures and Odivelas municipalities. Lisbon municipality registered the highest percentage of flood cases (35.8%).

The municipality of Vila Franca de Xira was affected both by frequent flash floods and by Tagus floods, which explains the large number of fatalities (313), where 295 fatalities were associated to a single Disaster event occurred in November 1967.

3. DATA AND METHODS

3.1 Spatial distribution of mortality

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		Landslide Disaster cases			Landslide Fatalities		
Municipality	**Area (km^2)**	**Number**	**%**	**Density (#100km^2)**	**Number**	**%**	**Density (#100km^2)**
Amadora	23.8	1	1.2	0.01	0	0.0	0.00
Cascais	97.4	0	0.0	0.00	0	0.0	0.00
Lisbon	85.0	56	68.3	0.56	32	69.6	0.32
Loures	169.1	6	7.3	0.06	2	4.3	0.02
Mafra	291.7	0	0.0	0.00	0	0.0	0.00
Odivelas	26.5	1	1.2	0.01	0	0.0	0.00
Oeiras	45.9	6	7.3	0.06	10	21.7	0.10
Sintra	319.2	5	6.1	0.05	0	0.0	0.00
Vila Franca de Xira	318.1	7	8.5	0.07	2	4.3	0.02
Total	**1376.7**	**82**	**100.0**	**0.82**	**46**	**100.0**	**0.46**

In the same period 82 Disaster landslide cases and 46 landslide fatalities were counted in the Great Lisbon Area.

Vila Franca de Xira municipality stands out with the highest flood density (3.13/100km^2) and Lisbon with the landslide density (0.32/100km^2).

3. DATA AND METHODS

3.2 Temporal trends of mortality

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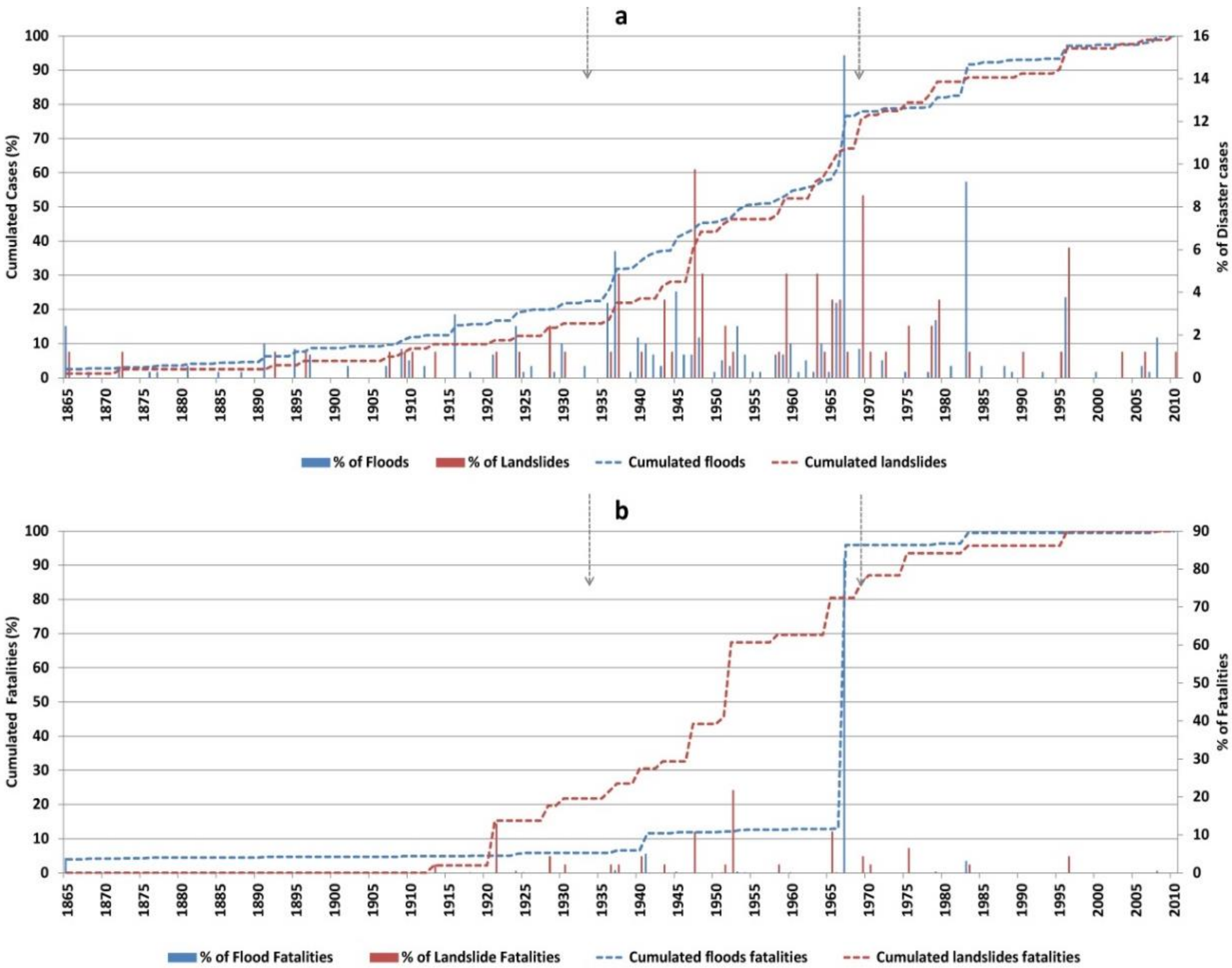

Annual distribution of disastrous floods and landslides (a) and fatalities (b) caused by disastrous floods and landslides

1865–1934

- below-average number of cases (1.2 floods and 0.2 landslides per year).
- average mortality per year (0.4 and 0.1 fatalities/year for floods and landslides, respectively) is approximate to average values for the complete time series (0.6 and 0.2 fatalities/year for floods and landslides, respectively).
- accounts for 5.8% and 0.2% of the total number of fatalities associated with floods and landslides, respectively.

3. DATA AND METHODS

3.2 Temporal trends of mortality

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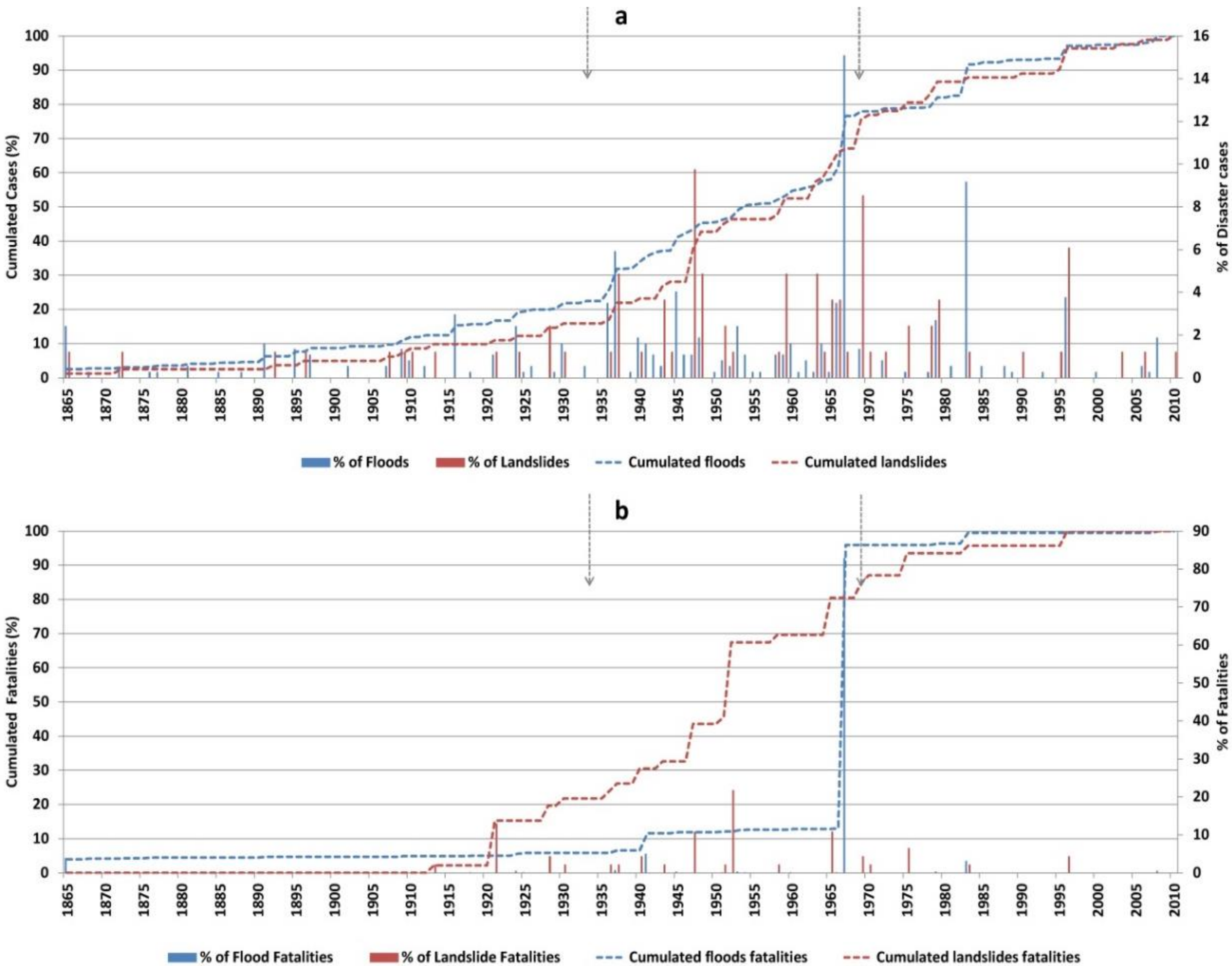

1935–1969

- this period registered the highest mean annual number of flood and landslide cases (5.9 floods and 1.4 landslides per year).
- The mean annual mortality associated with HG hazards was highest during this period, with a total of 90.1% and 63% fatalities associated with floods and landslides, respectively.

Annual distribution of disastrous floods and landslides (a) and fatalities (b) caused by disastrous floods and landslides

3. DATA AND METHODS

3.2 Temporal trends of mortality

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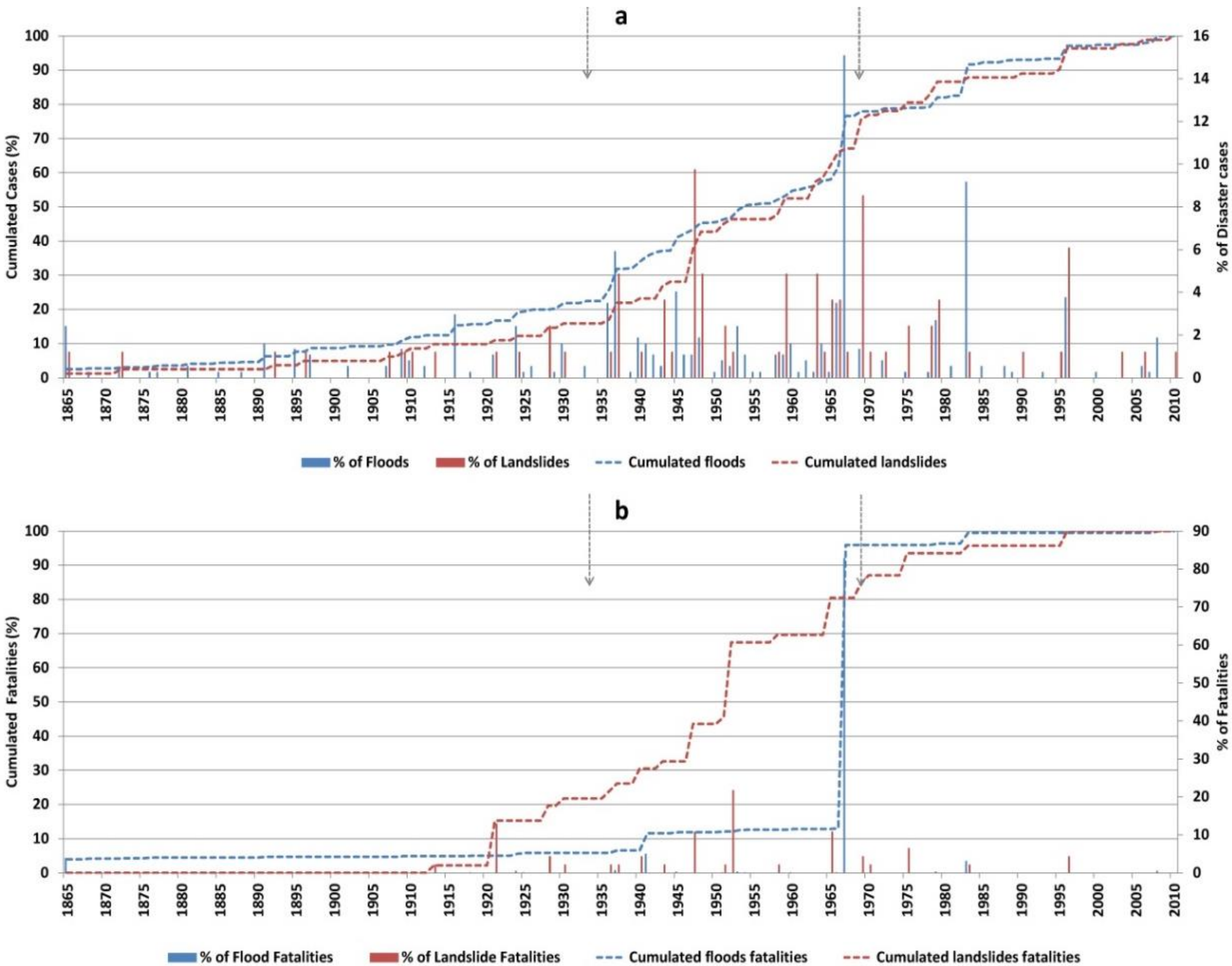


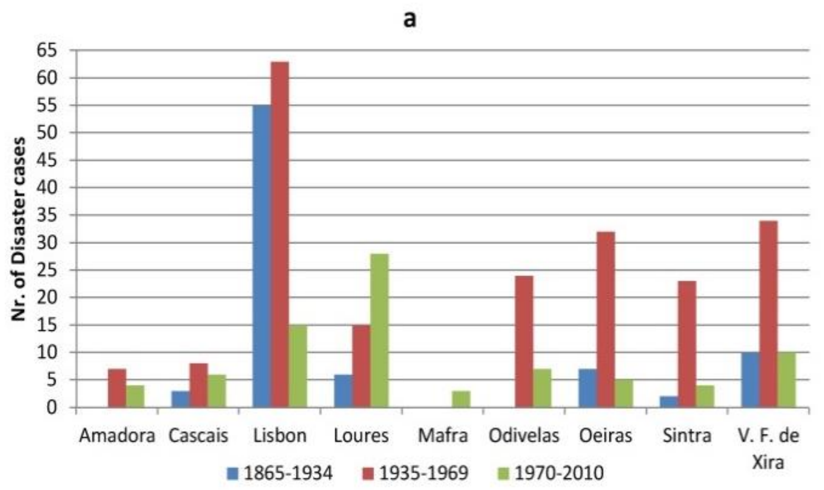
Annual distribution of disastrous floods and landslides (a) and fatalities (b) caused by disastrous floods and landslides

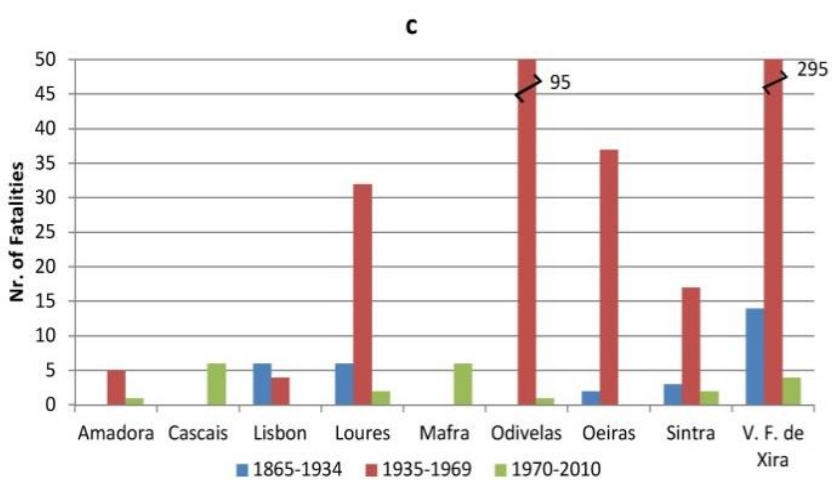
1970–2010

- accounts 22.1% and 24.4% of flood and landslide cases, respectively (2.1 flood/year and 0.5 landslide/year on average).
- Fatalities registered a significant decrease in the number of deaths/year in comparison with the previous periods.
- Annual fatalities associated with landslides correspond to 15.2% and the annual average is 0.2 fatalities.

3. DATA AND METHODS

3.2 Temporal trends of mortality





Number of Disaster cases caused by disastrous floods (a) and number of fatalities caused by disastrous floods (c)

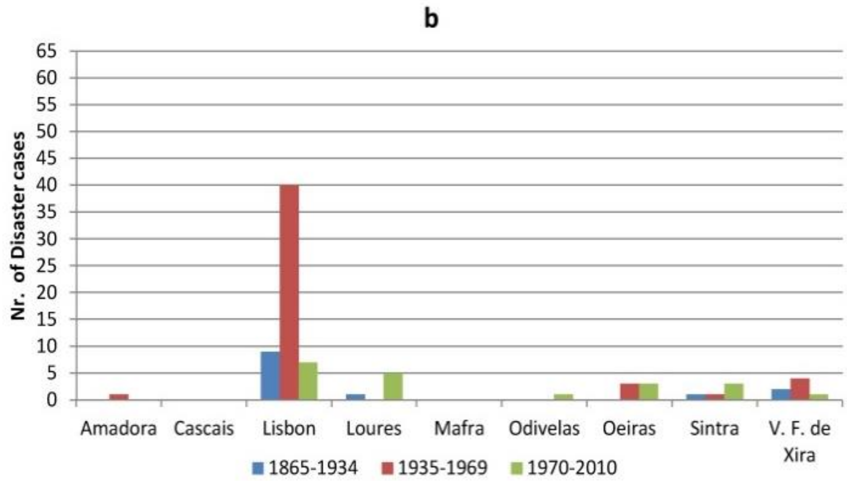
Lisbon municipality stands out with the highest number of flood cases in 1865-1934 and 1935-1969.

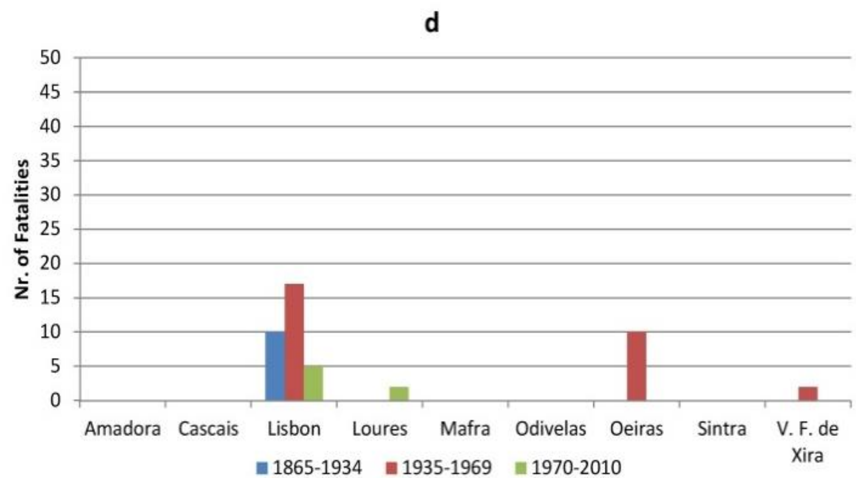
Vila Franca de Xira, Oeiras, Odivelas and Sintra also registered most of the Disaster flood cases (a), associated with the flash flood event of November 1967, while Loures registered the highest number of Disaster flood cases in the last period, associated with the flash flood event of November 1983.

The period 1935-1969 was characterized by more flood mortality, especially in Vila Franca de Xira, Odivelas, Oeiras and Loures (c), the most affected municipalities by the November 1967 flash flood.

3. DATA AND METHODS

3.2 Temporal trends of mortality





Number of Disaster cases caused by disastrous landslides (b) and number of fatalities caused by disastrous landslides (d)

The highest number of landslide Disaster cases was registered in Lisbon municipality in the period of 1935-1969 (b) while the highest number of landslide fatalities was registered in Lisbon and Odivelas municipalities (d).

In the last time period landslide cases occurred widespread (Lisbon, Loures, Odivelas, Oeiras, Sintra and Vila Franca de Xira), but landslide mortality was only registered in Lisbon and Loures (d).

3.3 Gender tendencies in mortality

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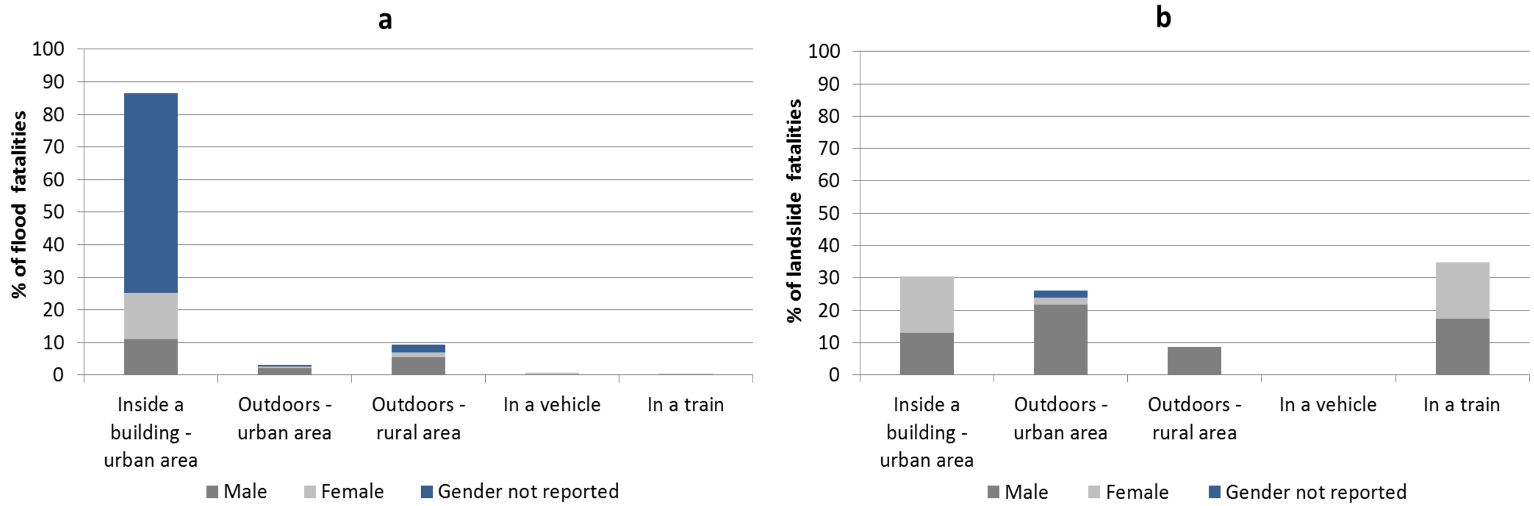
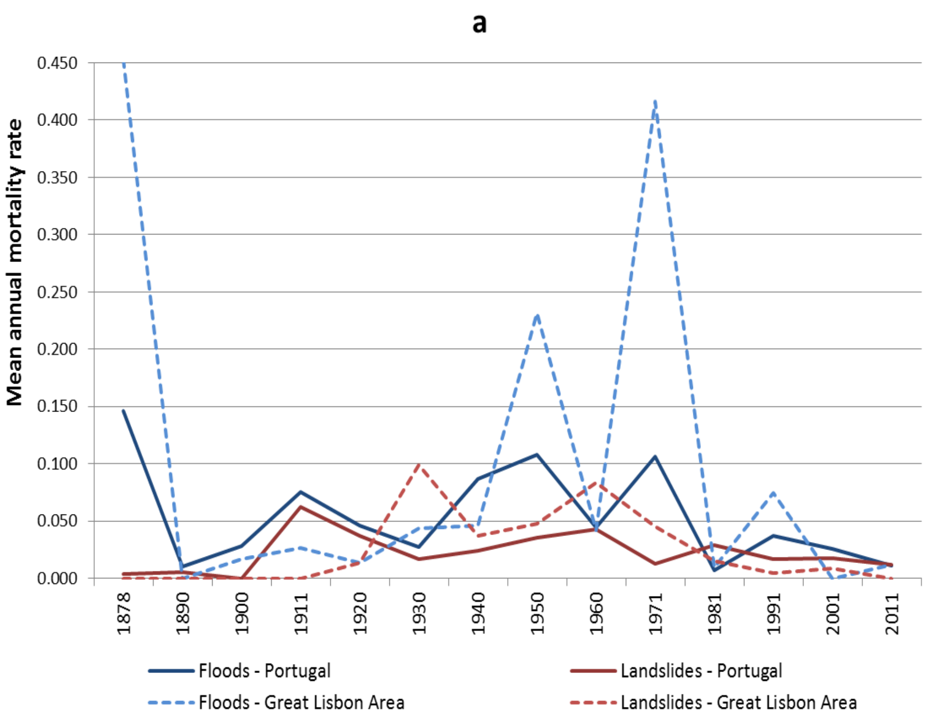
Circumstances surrounding the flood (a) and landslide (b) fatalities per gender



- **Flood fatalities were dominant inside buildings** in urban areas, while in the case of landslide fatalities only corresponds to 30% of total landslide fatalities. **Landslide fatalities were higher inside a train.**
- The highest percentage of fatalities with gender not reported occurred inside buildings corresponding to fatalities generated by floods.
- **Male fatalities** registered outdoors in urban and rural areas as a consequence of a Disaster flood are **3 times higher than female fatalities** in the same surroundings. This difference increases in the case of landslide fatalities observed outdoors.
- The number of women is similar to men concerning fatalities registered in buildings. These results are probably associated with the HG disaster type (e.g. flash flood) that affected residential buildings with entire families.

3.4 Individual and societal risk



Mean annual mortality rates per time period adjusted to population census) for flood and landslide cases that caused fatalities

- **The mortality rate is higher for floods than for landslides**, except in the 1930s and 1960s of the 20th century.
- **Flood mortality rates maximum in 1878** that corresponds to a very wet year that generated severe floods in Portugal (Trigo et al. 2014). The mortality rate peak is also a consequence of the low number of exposed population at that time (4.0×10^5 inhabitants).
- **Flood mortality rates peak registered in 1971s decade**, as a consequence of the November 1967 flash flood that caused at least 446 fatalities in the Great Lisbon Area, according to the Disaster database (Trigo et al. 2015).
- The landslide mortality rate was greatest in 1930 and reached a secondary peak in 1960s .
- **Both flood and landslide fatality rates are very low in the first decades of the 21st century.**

3. DATA AND METHODS

3.4 Individual and societal risk

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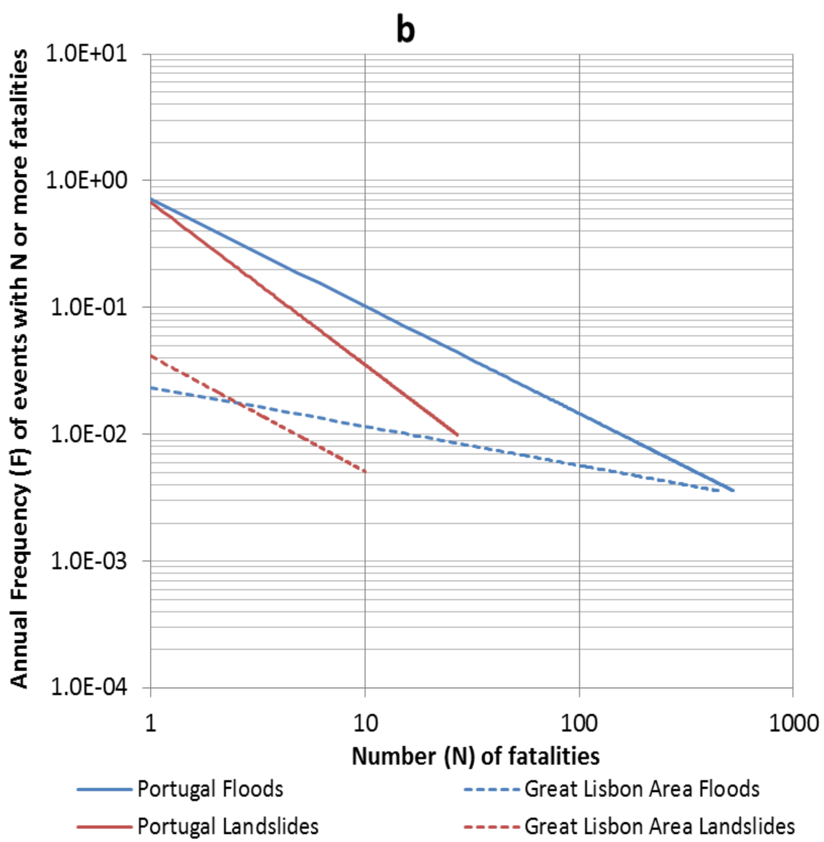

Frequency versus consequences (b) for flood and landslide cases that caused fatalities

- **The probability of DISASTER cases with fatalities is consistently higher for floods than for landslides**, independently of the number of fatalities considered, which reflects the large difference observed in the number of flood and landslide cases per year (Pereira et al. 2015).

- The annual frequency of one or more fatal floods is higher than the landslide fatal floods when 6 or more fatalities were registered getting very close to the national flood F-N curve for 500 or more fatalities.

- The maximum annual number of fatalities associated with flood Disaster cases in Great Lisbon Area range from 1 to 446 fatalities .

4. CONCLUDING REMARKS

- This study demonstrate the **absence of any exponential growth with time of hydro-geomorphologic cases and associated fatalities** in the Great Lisbon Area.

- The temporal trend of disaster mortality rate in this area is distinct for floods and landslides**. Mortality associated with floods decreases with time since the 80´s of the XX century, while mortality associated with landslides started to decrease a decade earlier.**

- **The temporal evolution of flood fatalities reflects the implementation of territorial management policies in the last four decades.** In the 1960s, most fatalities caused by floods and flash floods occurred in slums located in the Lisbon periphery. These slums have progressively been eliminated and nowadays, although some residential areas are located in hazardous areas, recent buildings are resistant and normally do not collapse as a result of a flood.

- **Landslide fatalities in the Great Lisbon Area occurred as a consequence of isolated falls,** while most common landslides in this area are slow moving landslides that usually cause structural damages in buildings and not human casualties. Although even today, buildings are often located on hazardous slopes.

4. CONCLUDING REMARKS

- **Spatial patterns of flood and landslide mortality in the Great Lisbon Area** are explained by the unequal distribution of predisposing conditions to flood and landslide occurrence (geomorphologic and hydrologic), change of land use and population exposure in the highly populated municipalities, and the evolution of social vulnerability to hydro-geomorphologic hazards.

- Very often, flood and landslide related deaths are linked to unnecessary **risk-taking behavior and to poor land management**, with buildings/ infrastructures erected on flooded areas or on unstable slopes that increase population exposure to hydro-geomorphologic hazards.

- Gender distribution of disaster fatalities showed that **flood and landslide victims are mostly male who are more exposed to disastrous floods and landslides in Portugal.** These results can be explained by cultural reasons, related to the social role of the breadwinner that exposes men to hazardous occupations. In addition, men often assume risk behaviors outdoors and act with a false sense of security inside vehicles (e.g., driving a car in flooded roads, cross bridges in flood situations).

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Thank you for your attention!