Environmental Hazards and Risk Assessment and Management
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Landslide Societal Risk in Portugal in the period 1865-2015

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LJUBLJANA SLOVENIA EU

1. OBJECTIVES

In this work we explore the mortality patterns resulting from damaging landslides occurred in Portugal in the period 1865-2015.

Objectives:

(i) analyse the spatio-temporal distribution of damaging landslides;

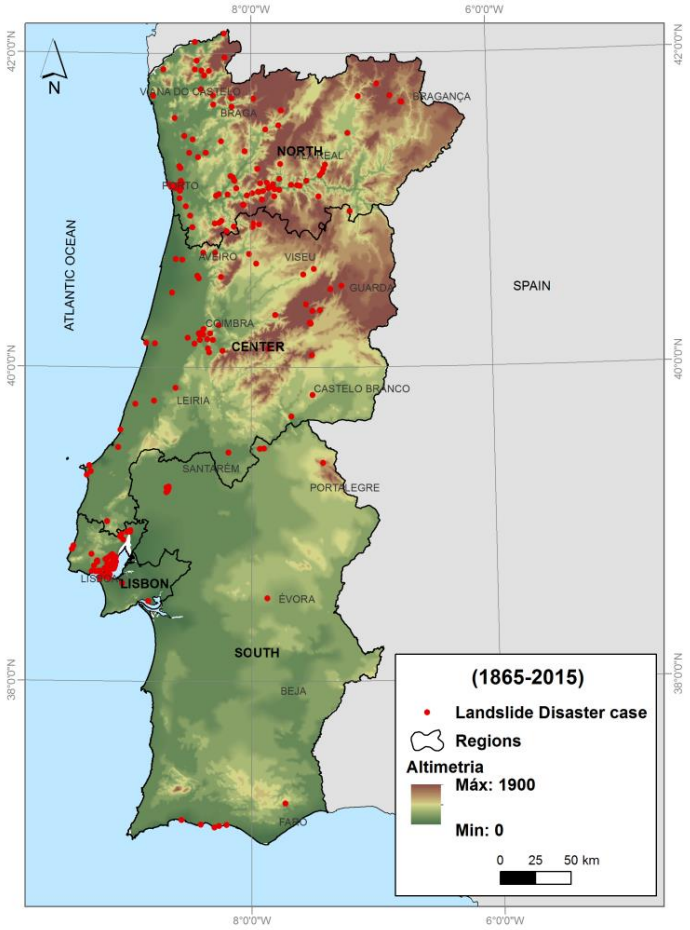
(ii) analyse the temporal evolution of fatal landslides;

(iii) analyse the spatio-temporal distribution of landslide fatalities;

(iv) identify the most deadly landslide types;

(v) verify gender tendencies in landslide mortality;

(vi) evaluate the individual and societal risk.



2. DATA AND METHODS

Landslide societal risk in Portugal (1865-2015) was based on an updated version of the **Disaster database** until 2015 and updates the work developed by Zêzere et al. (2014) about the Portuguese Disaster database and Pereira et al.(2016) about related landslide fatalities (1865-2010).

The Disaster database was built under the assumption that social consequences (fatalities, injuries, missing, homeless and evacuated people) of landslides are relevant enough to have been reported by **newspapers**, which were used as the data source.

Each DISASTER case includes details on the **disaster characteristics** (landslide subtype, date of occurrence, location, and triggering factor) and **damages** (structural damages and social consequences [human damage, gender of fatalities, and circumstances surrounding the fatalities]).

2. DATA AND METHODS

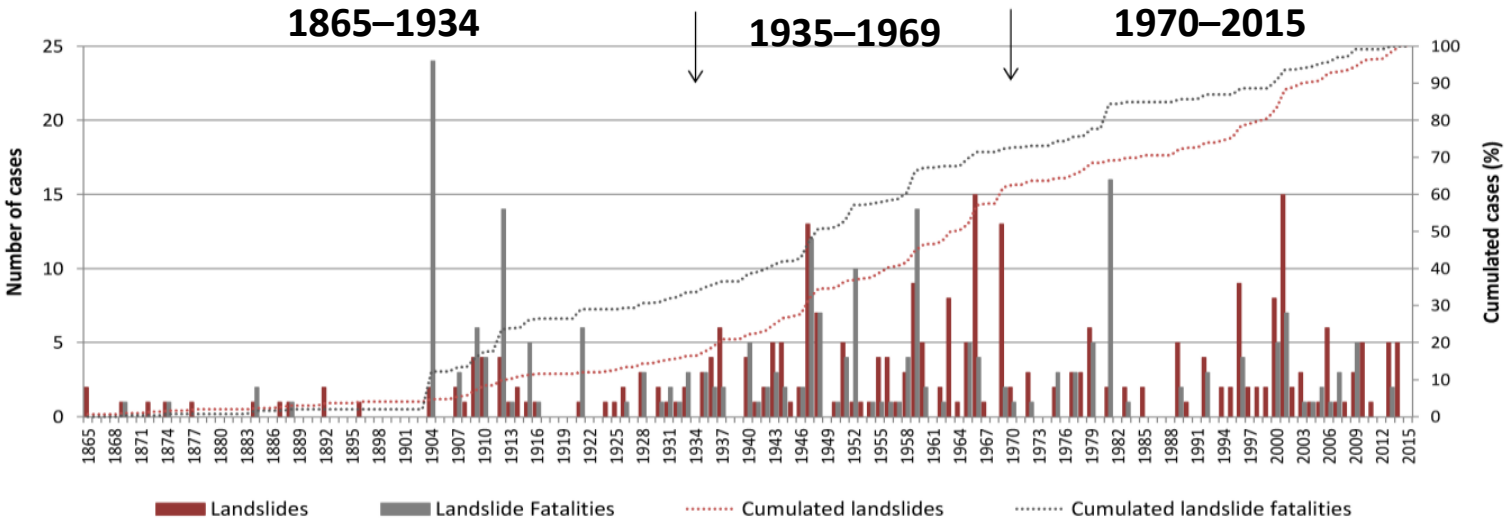
Individual risk was evaluated using mortality rates for landslides, which were calculated based on years with population census in Portugal (usually every 10 years).

The **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.

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

3. RESULTS

3.1 Temporal Trends of Mortality

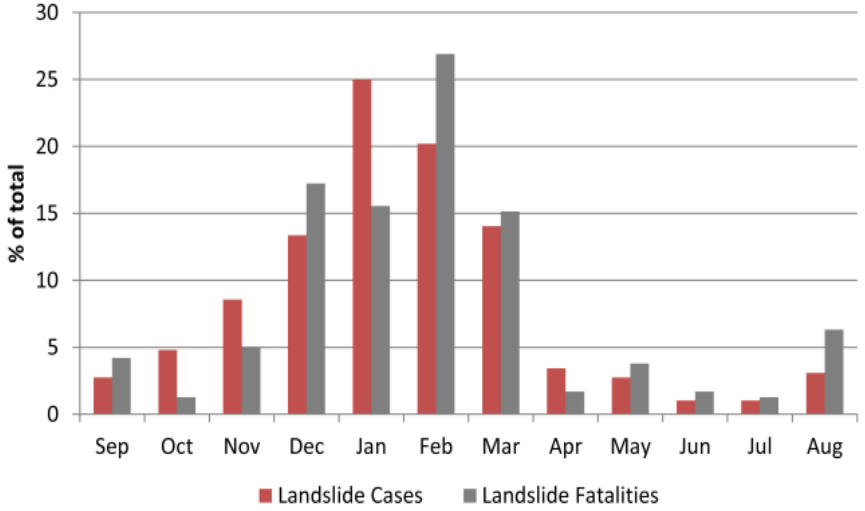


Annual distribution of landslides (red) and landslide fatalities (grey) (1865-2015)

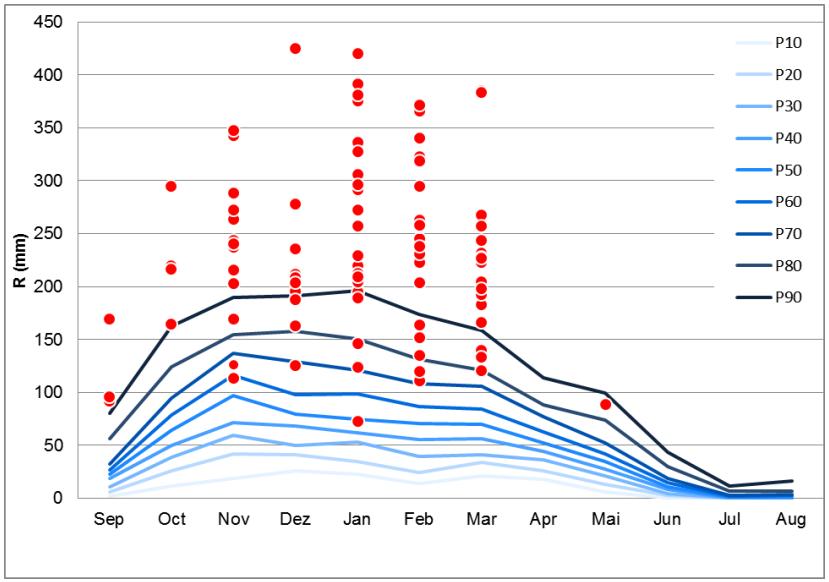
	1865–1934	1935–1069	1970–2015	1865–2015
Number of cases	47	133	111	291
% of total cases	16.2	45.7	38.1	100.0
Landslide cases/year	0.7	3.8	2.4	1.9
Number of fatalities	80	92	66	238
% of total fatalities	33.6	38.7	27.7	100.0
Fatalities/year	1.1	2.6	1.4	1.6

3. RESULTS

3.1 Temporal Trends of Mortality



Monthly distribution of landslide disaster cases and landslide fatalities

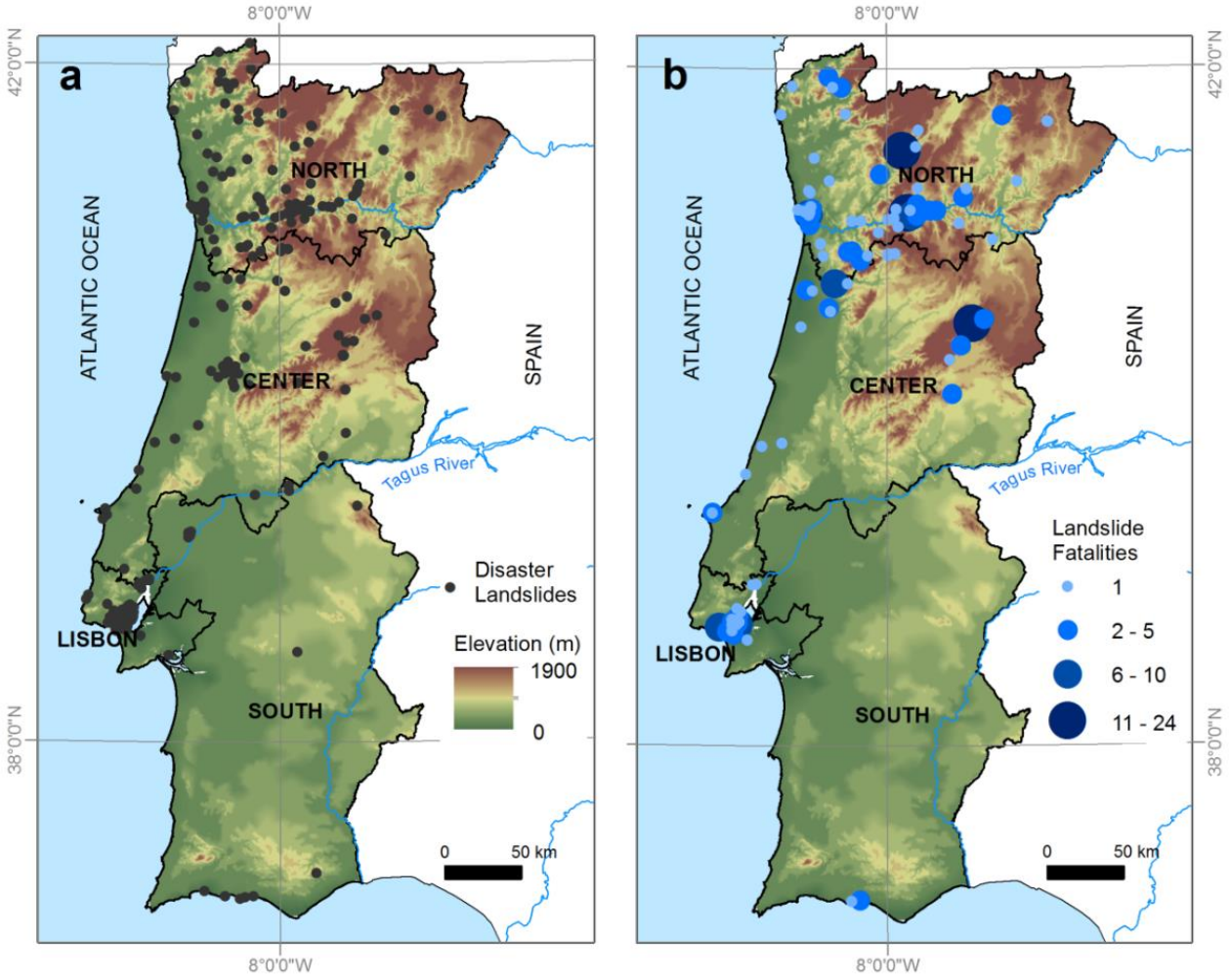


Monthly rainfall percentiles for Lisboa-Geofísico rain gauge. (30-day cumulative absolute antecedent rainfall for local landslides events are represented with dots).

Landslide cases and landslide fatalities monthly distribution evidences a clear concentration during the **autumn and the winter seasons** from December to March.

3. RESULTS

3.2 Spatial distribution

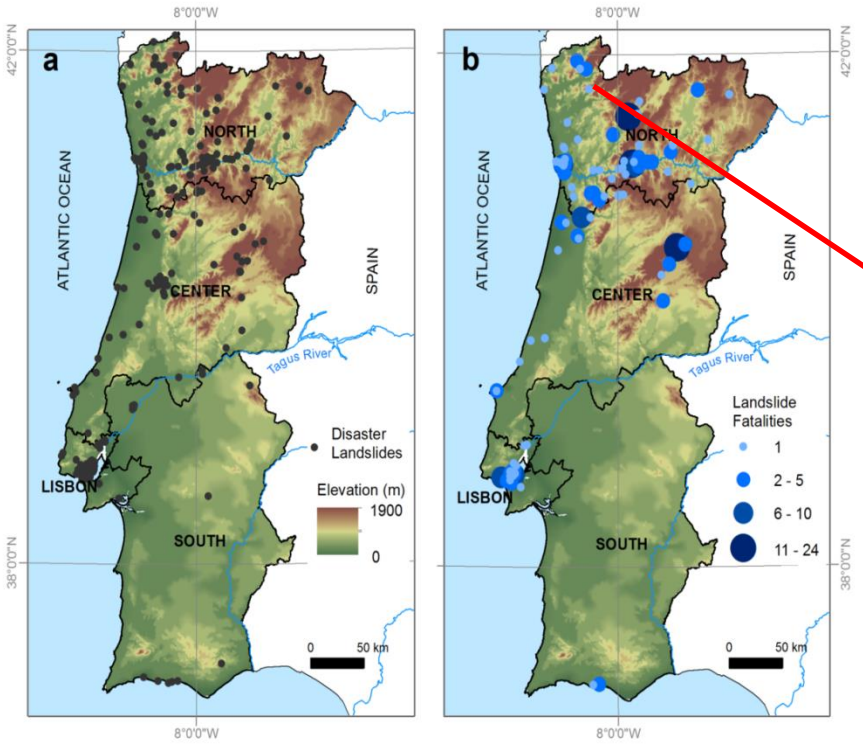


a) Portugal - 60% of the landslide Disaster cases were related to falls, which were also associated with the highest percentage of fatalities (54%), followed by flows (36%).

b) Landslide fatalities are almost completely constrained **northwards of the Tagus valley** where geologic and geomorphologic conditions are more landslide prone than in the south.

3. RESULTS

3.2 Spatial distribution



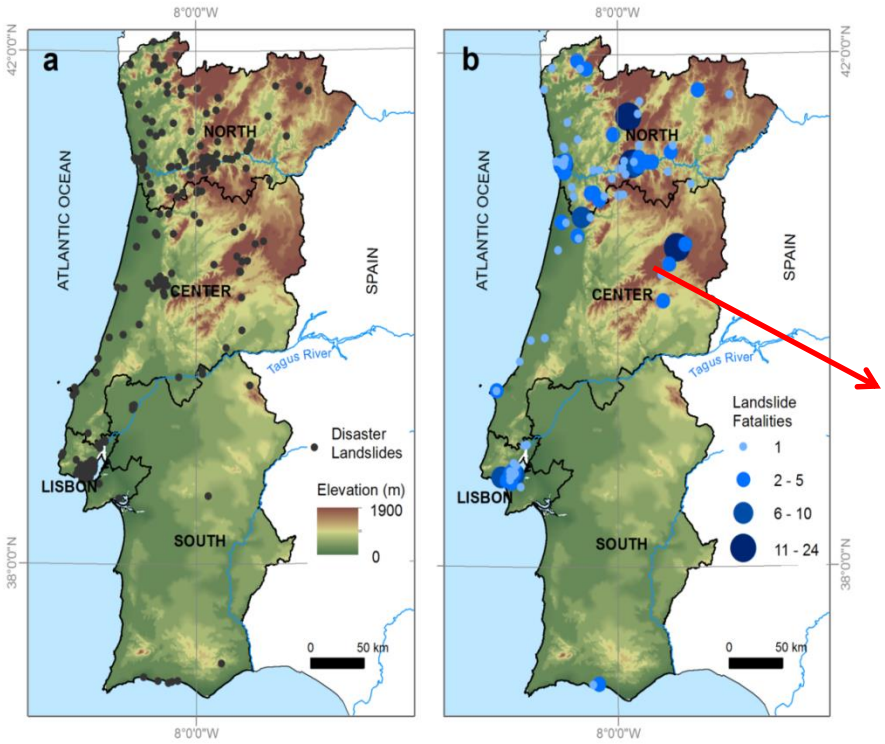
North region

- 41.2% of disaster landslides
- 58.4% of landslide fatalities
- Mountainous region with metamorphic and granitic rocks where fatal flows and falls frequently occur.

Arcos de Valdevez; December, 2000;
Debris flow, 4 fatalities

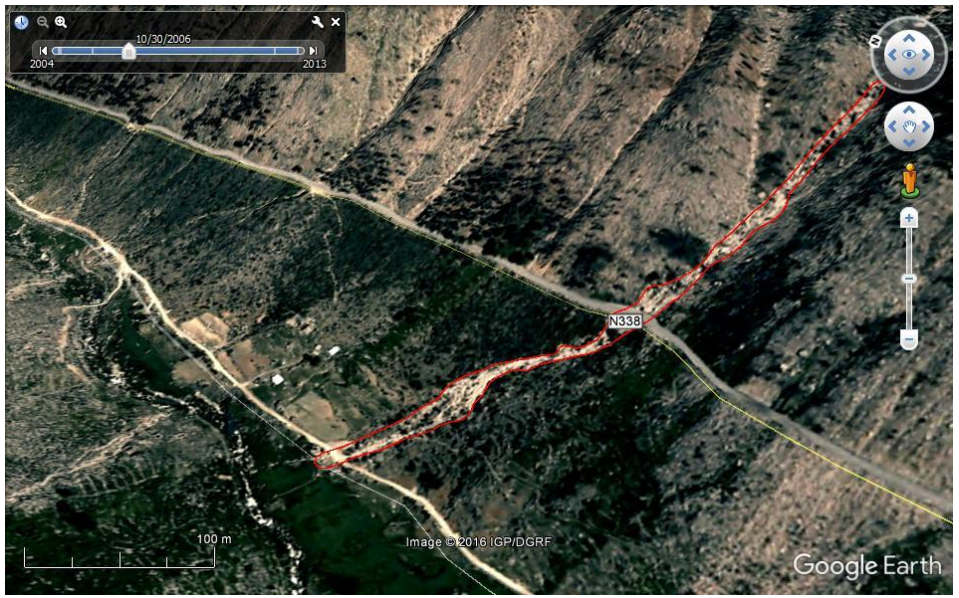
3. RESULTS

3.2 Spatial distribution



Center region

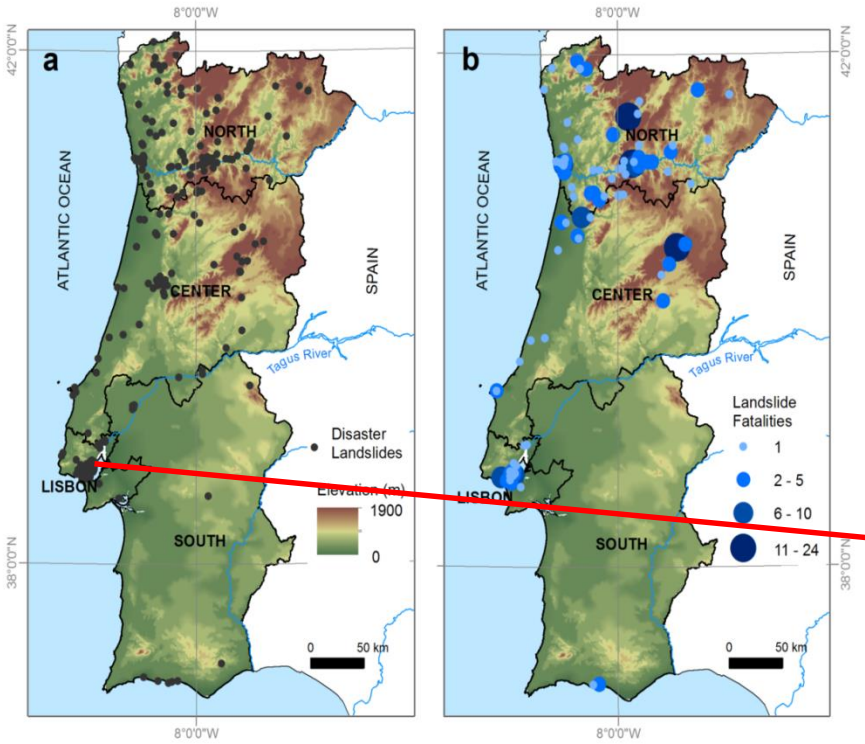
- 21% of total landslide cases;
- 19.7% of landslide fatalities;
- Falls and flows are the most frequent fatal landslides



Vale do Zêzere, Manteigas; October, 2005
Debris flow

3. RESULTS

3.2 Spatial distribution



The mortality hotspot observed in the Lisbon region is explained both by natural conditions and by the high population density that increase exposure to landslide risk.

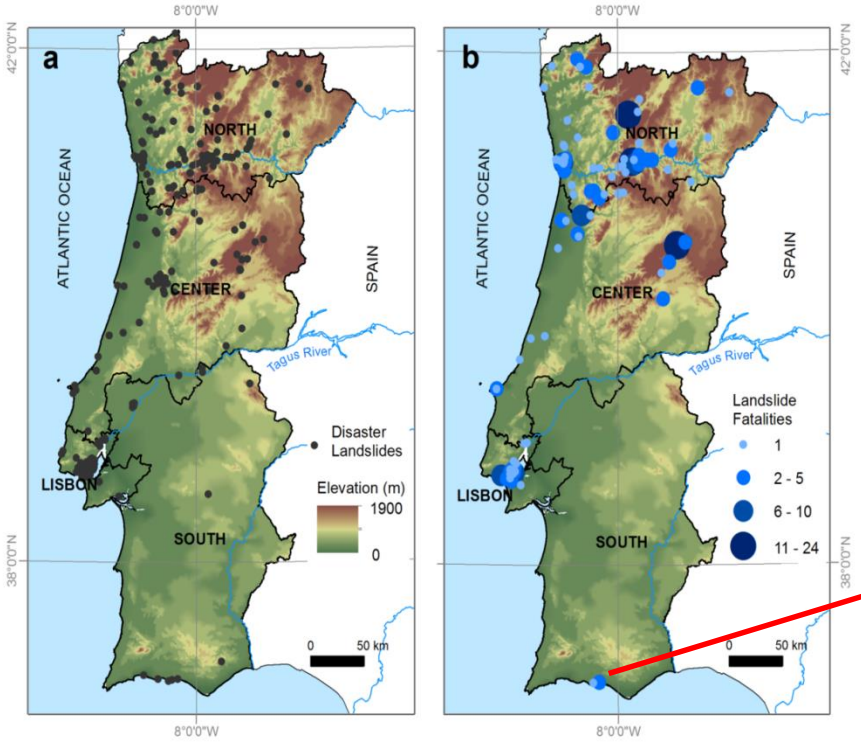
Lisbon region

- 33.3% of landslide cases;
- 23.2% of landslide mortality;
- Dominance of slow-moving landslides affecting clay rich sedimentary rocks and soils.

Alrota, Loures; January, 2001
Rotational slide

3. RESULTS

3.2 Spatial distribution



Landslide fatalities have been constrained to coastal cliffs, and have grown in number in recent years, reflecting the increasing exposure associated with careless intensive use of the coastal areas for tourism and leisure.

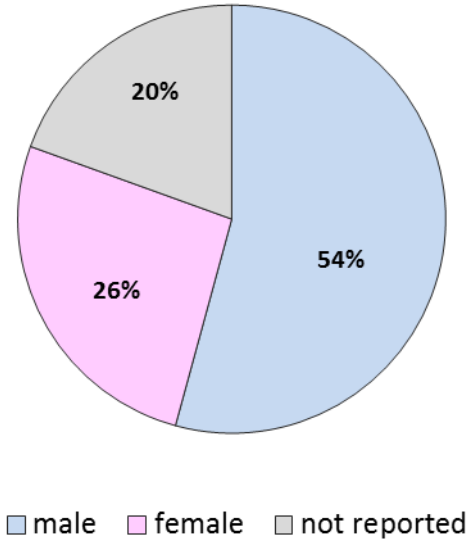
South region

- 5.8 % of landslide disaster cases;
- 2.5 % of landslide fatalities
- Presence of low landforms

Maria Luísa Beach, Albufeira; August, 2009
Rock fall; 5 fatalities

3. RESULTS

3.3 Gender Tendencies in Mortality



The number of male fatalities is more than double of the equivalent for female fatalities.

Excluding the South region where female fatalities were dominant, in the most recent analyzed period (1970–2015) in the other regions **male fatalities are dominants in spatial and temporal terms**.

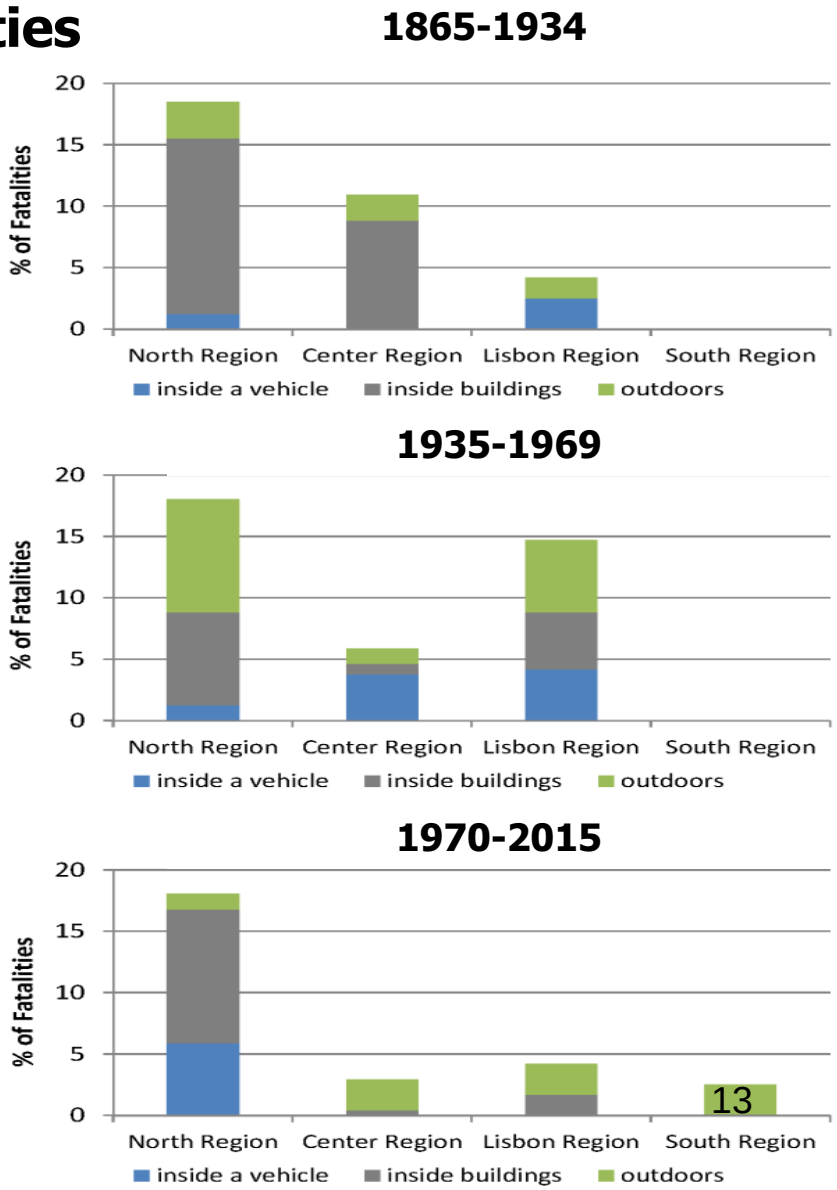
3. RESULTS

3.3 Circumstances surrounding fatalities

Portugal - **49.2% of total landslide fatalities occurred inside buildings**, mostly in the **North region**.

Fatalities occurring inside vehicles are increasing in time while fatalities occurring outdoors registered a slightly decrease.

Fatalities occurred inside buildings tends to maintain in time.

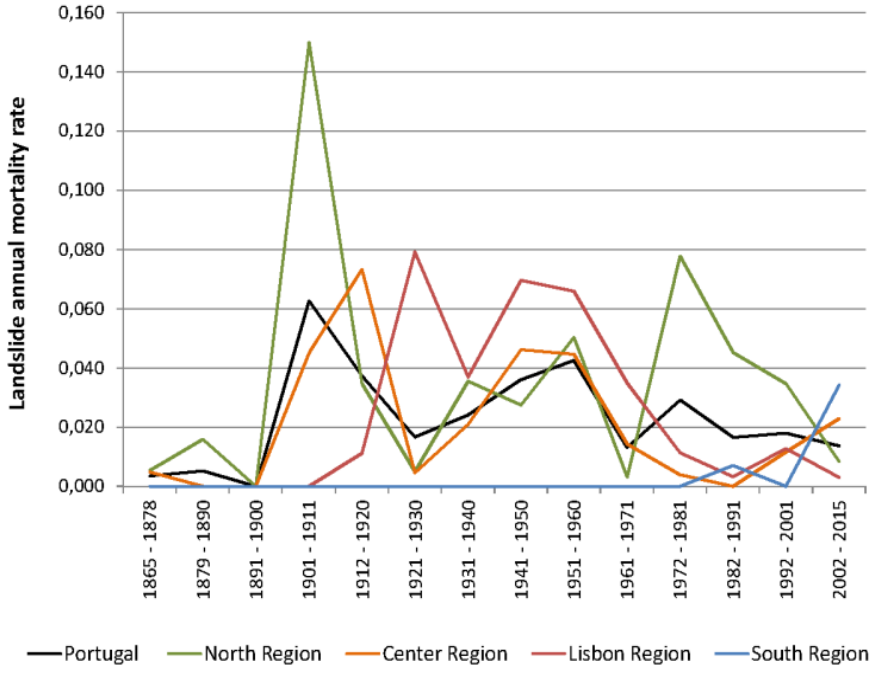


inside a vehicle inside buildings outdoors

3. RESULTS

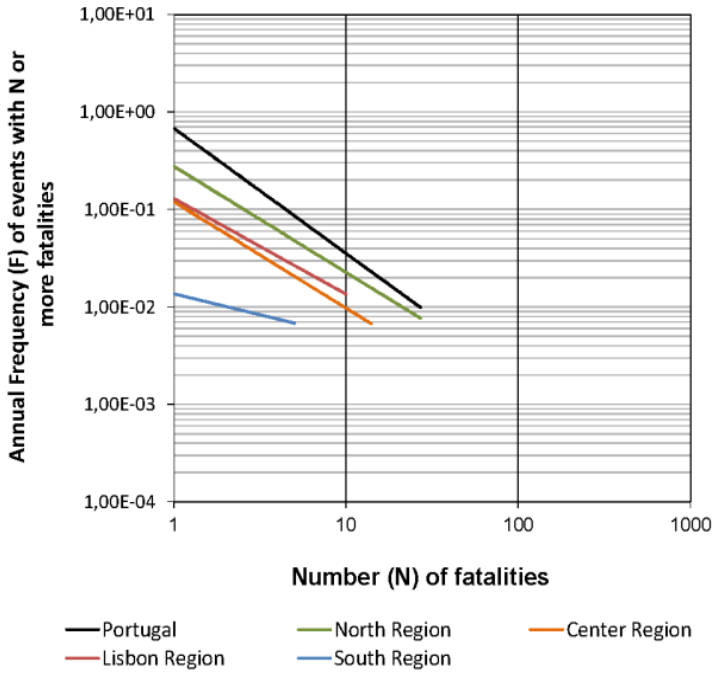
3.4 Individual and Societal Risk

Mean annual mortality rates per time period



In Portugal landslide mortality rate did not show any clear tendency in time.

F-N curves



Annual frequency of fatal landslides is **highest in the North region** and lowest in the south region.

The **societal risk** in Portugal is considered **unacceptable for landslides**.

4. CONCLUSIONS

- The total **number of fatalities** resulting from landslide disasters is certainly underestimated because deaths that did not occur immediately after the landslide would not have been reported, and then it is not possible to asses these features using newspapers as the data source.

- The temporal trends of disaster landslides and corresponding fatalities demonstrate the **absence of any exponential growth with time**.

- **Falls and flows** were responsible for the majority of fatalities associated with landslides in Portugal.

- **Spatial distribution of landslide mortality** can be related to factors other than climate, such as the unequal distribution of predisposing conditions to landslide occurrence (geomorphologic and hydrologic), changes on land use and population exposure to landslide hazard and the evolution of social vulnerability.

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4. CONCLUSIONS

- **Landslide fatality victims are mostly male** which can be explained by cultural reasons, related to the social role of the breadwinner that exposes men to hazardous occupations and men often assume risk behaviors outdoors and act with a false sense of security when are driving vehicles.

- **Frequency of landslide fatalities per gender and period** does not evidence any particular regional trend, not allowing for any conclusions regarding territorial inequalities.

Cabeceiras de Basto; November 1981;
Mud flow; 15 fatalities

- Despite the increasing quality of the building environment observed in the last decades due to the adoption and use of building construction techniques and codes most fatalities still occur inside buildings. These buildings improvements are not enough to resist very rapid landslides such as falls and flows. Even today these incidents are frequent **because buildings are often located on hazardous slopes.**

Thank you for your attention!

http://www.ceg.ulisboa.pt/forland/

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