CEDIM AG – Bulgarian Delegation
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Damage and risk estimation in earthquake prone communities

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Preliminary estimation of seismic risk distribution in Bulgaria

Input data provided by the Bulgarian partners:

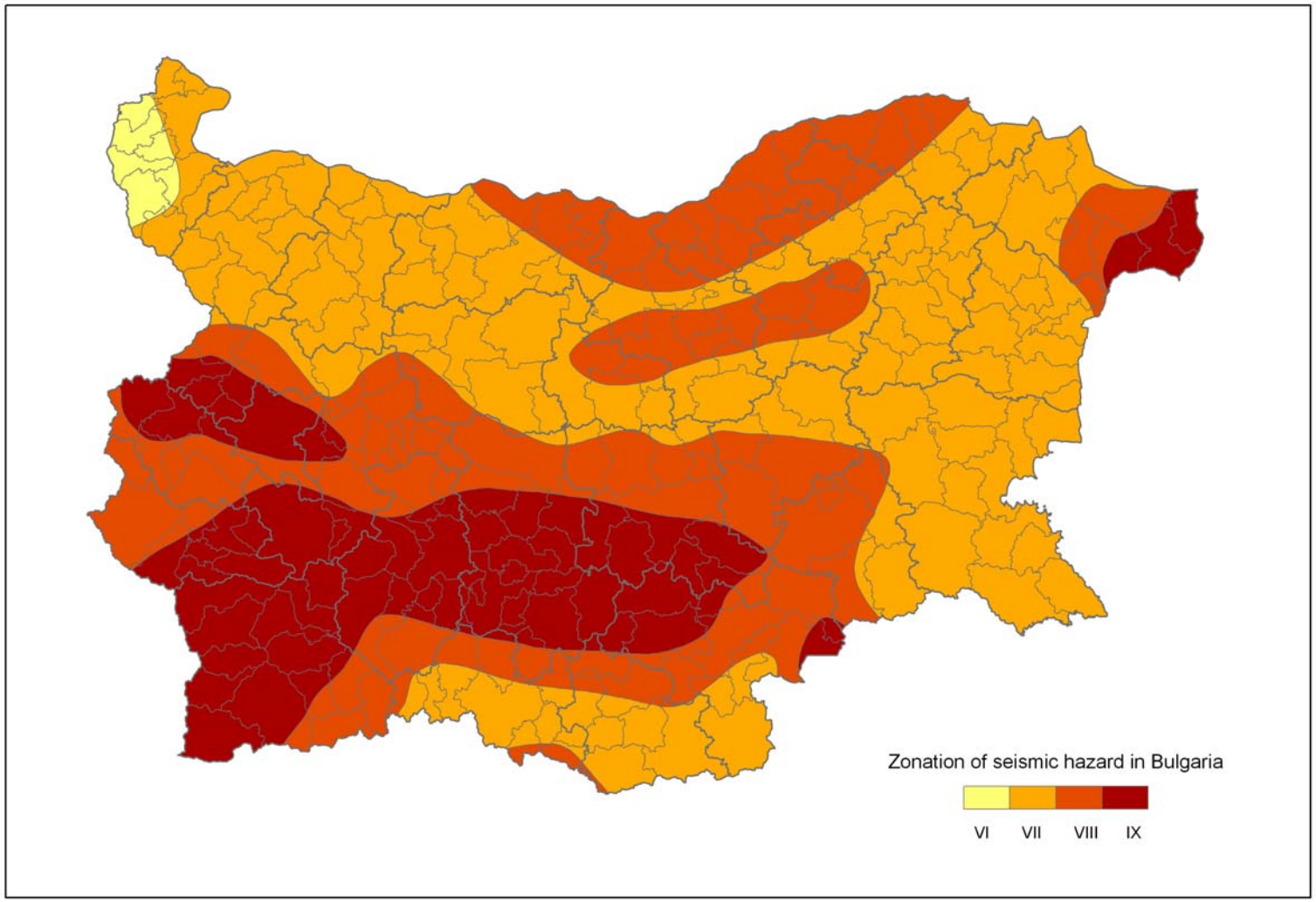
- Map of seismic hazard (in terms of intensities). There are zones of intensity VI, VII, VIII and IX.
- Grid of districts (provinces). There are 28 provinces (oblasts).
- Grid of municipalities (communities). There are 263 communities (obschinas) in the country.
- Population distribution in communities.
- Composition of building types (reinforced concrete, masonry, other) in provinces.
- Indication of the status of communities (urban, rural).

Computational cells

Having intersected the layer of seismic hazard (zones of different seismic intensities VI, VII, VIII, IX) with the layer of administrative boundaries of communities (263 communities), we obtain 421 computational cells.

The cells are too large for detailed analysis of potential losses, especially for generating probable earthquake scenarios. Therefore, it is strongly recommended to consider smaller computational cells (settlements), which will require more detailed input information.

Distribution of seismic hazard in Bulgaria



Vulnerability analysis

Vulnerability models are constructed on the base of the vulnerability classification of the European Macroseismic Scale (EMS-98).

For constructing the vulnerability composition models in different computational cells (communities or settlements) we need information about the composition of the existing building stock in terms of building types.

For the time being the information is available only for provinces (districts). Therefore, more detailed data are required for differentiation and improvement of the models.

Vulnerability classification (EMS-98)

	Type of Structure	Vulnerability Class A	B	C	D	E	F
MASONRY	rubble stone, fieldstone	○					
	adobe (earth brick)	○	—				
	simple stone	····		○			
	massive stone		—	○	—		
	unreinforced, with manufactured stone units	····		○	—		
	unreinforced, with RC floors		—	○	—		
	reinforced or confined			····		○	—
REINFORCED CONCRETE (RC)	frame without earthquake-resistant design (ERD)	····		○	—		
	frame with moderate level of ERD		····		○	—	
	frame with high level of ERD			····		○	—
	walls without ERD		····	○	—		
	walls with moderate level of ERD			····	○	—	
	walls with high level of ERD				····	○	—
STEEL	steel structures			····		○	—
WOOD	timber structures		····		○	—	

○ most likely vulnerability class; — probable range;
····· range of less probable, exceptional cases

Composition of the residential building stock in districts of Bulgaria

Districts	Residential buildings - Total	Residential buildings by structure of building		
		Steel- concrete	Solid structure	Others
TOTAL	**2 127 378**	**95 329**	**1 578 921**	**453 128**
in towns	**750.992**	**60.344**	**606.531**	**84.117**
in villages	**1.376.386**	**34.985**	**972.390**	**369.011**
BLAGOEVGRAD	**79.384**	**5.484**	**61.453**	**12.447**
in towns	26.787	3.394	21.603	1.790
in villages	52.597	2.090	39.850	10.657
BURGAS	**98.614**	**7.580**	**81.101**	**9.933**
in towns	35.334	4.321	29.846	1.167
in villages	63.280	3.259	51.255	8.766
VARNA	**95.296**	**4.240**	**72.954**	**18.102**
in towns	48.272	3.328	39.571	5.373
in villages	47.024	912	33.383	12.729
VELIKO TARNOVO	**91.658**	**4.710**	**66.643**	**20.305**
in towns	29.178	3.076	21.743	4.359
in villages	62.480	1.634	44.900	15.946
VIDIN	**58.864**	**868**	**44.639**	**13.357**
in towns	12.848	513	11.161	1.174
in villages	46.016	355	33.478	12.183
VRATSA	**96.290**	**1.340**	**86.321**	**8.629**
in towns	27.512	983	24.123	2.406
in villages	68.778	357	62.198	6.223

GABROVO	**45.465**	**2.056**	**33.131**	**10.278**
in towns	17.982	1.381	13.895	2.706
in villages	27.483	675	19.236	7.572
DOBRICH	**60.519**	**1.481**	**44.398**	**14.640**
in towns	21.341	1.083	16.747	3.511
in villages	39.178	398	27.651	11.129
KARDZHALI	**52.327**	**1.044**	**19.964**	**31.319**
in towns	7.767	486	6.052	1.229
in villages	44.560	558	13.912	30.090
KYUSTENDIL	**62.763**	**2.781**	**47.332**	**12.650**
in towns	19.153	1.392	16.715	1.046
in villages	43.610	1.389	30.617	11.604
LOVECH	**78.980**	**1.651**	**65.957**	**11.372**
in towns	25.618	931	22.054	2.633
in villages	53.362	720	43.903	8.739
MONTANA	**86.292**	**1.899**	**63.556**	**20.837**
in towns	28.789	1.239	23.927	3.623
in villages	57.503	660	39.629	17.214
PAZARDZHIK	**87.923**	**4.194**	**68.985**	**14.744**
in towns	37.525	2.610	30.942	3.973
in villages	50.398	1.584	38.043	10.771
PERNIK	**64.863**	**5.876**	**46.274**	**12.713**
in towns	17.612	2.294	14.613	705
in villages	47.251	3.582	31.661	12.008

PLEVEN	**108.008**	**2.059**	**96.086**	**9.863**
in towns	39.816	1.594	35.888	2.334
in villages	68.192	465	60.198	7.529
PLOVDIV	**148.591**	**8.485**	**101.164**	**38.942**
in towns	56.101	5.895	41.468	8.738
in villages	92.490	2.590	59.696	30.204
RAZGRAD	**44.921**	**711**	**35.030**	**9.180**
in towns	12.443	565	10.622	1.256
in villages	32.478	146	24.408	7.924
RUSE	**67.018**	**3.284**	**54.070**	**9.664**
in towns	25.250	1.698	20.713	2.839
in villages	41.768	1.586	33.357	6.825
SILISTRA	**41.430**	**884**	**24.829**	**15.717**
in towns	11.475	577	8.082	2.816
in villages	29.955	307	16.747	12.901
SLIVEN	**60.543**	**1.674**	**46.814**	**12.055**
in towns	27.002	1.296	21.060	4.646
in villages	33.541	378	25.754	7.409
SMOLYAN	**35.580**	**2.527**	**14.859**	**18.194**
in towns	11.418	1.665	6.612	3.141
in villages	24.162	862	8.247	15.053
SOFIA REGION	**149.719**	**6.553**	**118.992**	**24.174**
in towns	41.422	2.396	36.450	2.576
in villages	108.297	4.157	82.542	21.598

SOFIA CAP.	**97.320**	**12.827**	**79.824**	**4.669**
in towns	68.018	9.898	55.971	2.149
in villages	29.302	2.929	23.853	2.520
STARA ZAGORA	**90.051**	**3.241**	**55.972**	**30.838**
in towns	26.559	2.015	19.677	4.867
in villages	63.492	1.226	36.295	25.971
TARGOVISHTE	**45.820**	**2.399**	**24.158**	**19.263**
in towns	12.050	1.807	8.089	2.154
in villages	33.770	592	16.069	17.109
HASKOVO	**75.365**	**2.541**	**52.984**	**19.840**
in towns	30.090	1.896	24.002	4.192
in villages	45.275	645	28.982	15.648
SHUMEN	**56.525**	**1.539**	**31.789**	**23.197**
in towns	18.720	1.196	12.882	4.642
in villages	37.805	343	18.907	18.555
YAMBOL	**47.249**	**1.401**	**39.642**	**6.206**
in towns	14.910	815	12.023	2.072
in villages	32.339	586	27.619	4.134

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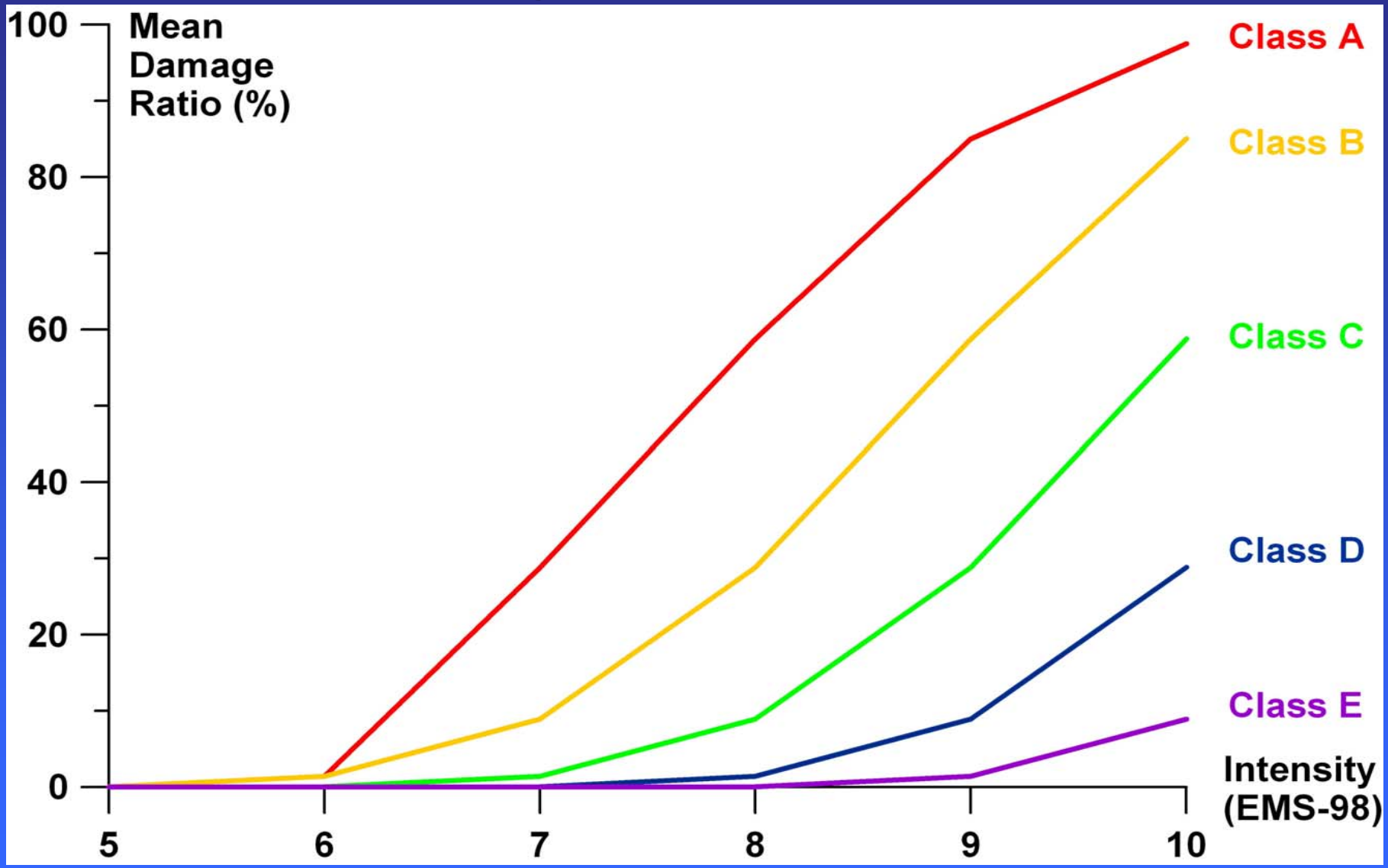
Vulnerability functions for different vulnerability classes of the EMS-98



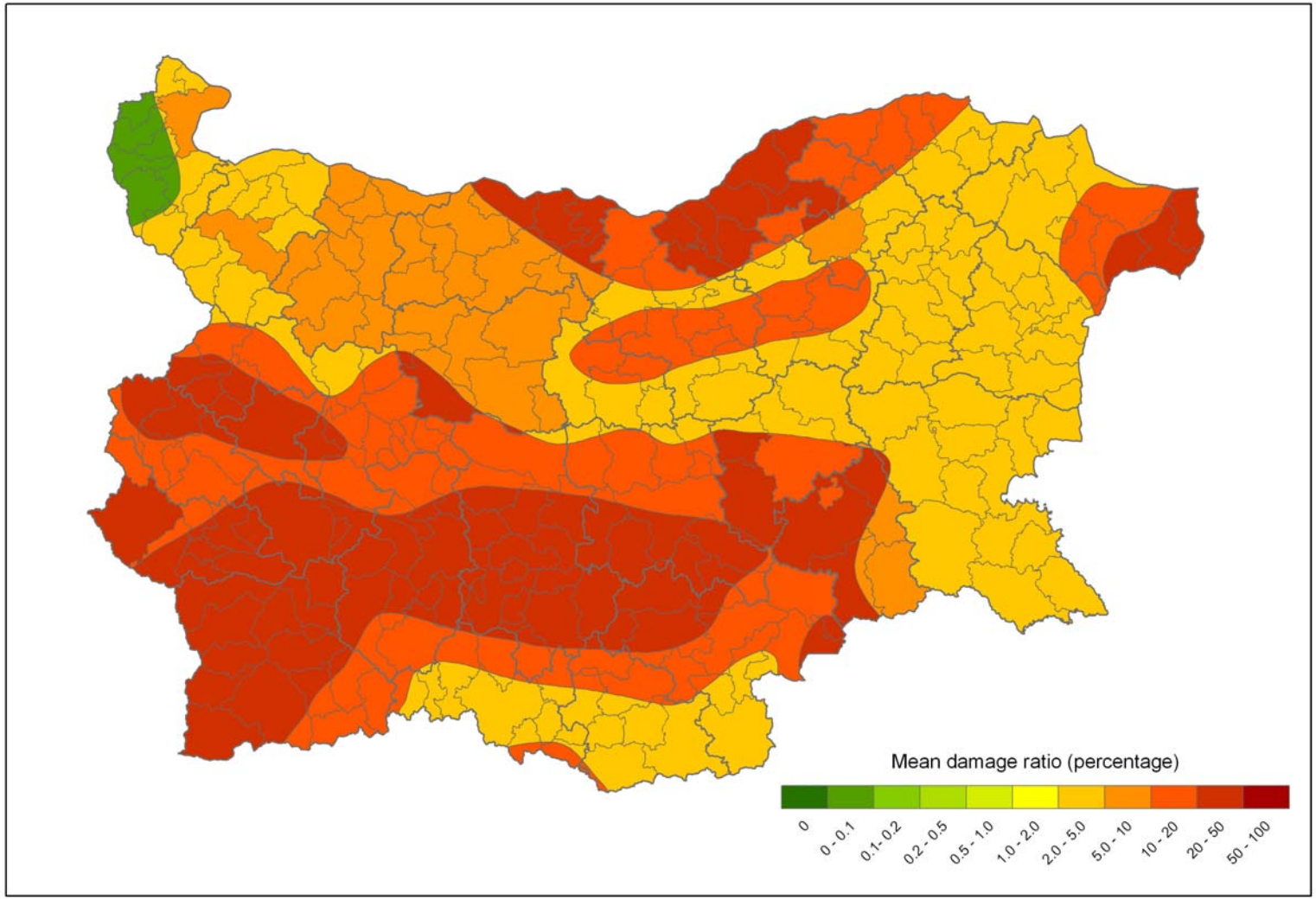
Estimation of mean damage for a cell

Combining the seismic input with the vulnerability functions we can estimate the damage for buildings corresponding to different vulnerability classes.

The mean damage ratio for the whole building stock in a cell can be estimated as the arithmetic mean of those of all buildings in the cell:

$$MDR = \Sigma\, MDR_i / 100 \quad (\%)$$

Estimated mean damage ratio (MDR,%) in cells



Estimation of potential losses

Potential direct losses due to the structural damage to the residential building stock can be estimated as a combination of the mean damage ratio (MDR, %) and the exposed assets (in terms of replacement costs for the buildings).

As a first approximation (assuming that the total asset value in a community is proportional to the number of inhabitants) we can estimate the comparative distribution of the risk potential, as the product of MDR and the number of inhabitants in communities.

The losses are calculated for communities, dissolving the computational cells.

Estimated distribution of seismic risk potential