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IFSTTAR

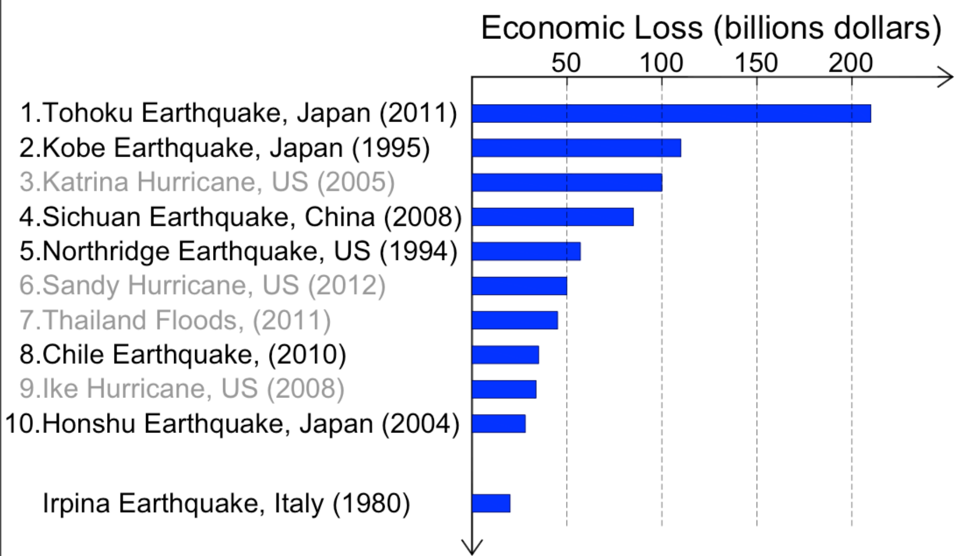
Sismologie Urbaine : Analyse des conséquences d'un séisme en France en terme de pertes économiques

Ismael Riedel - Philippe Guéguen

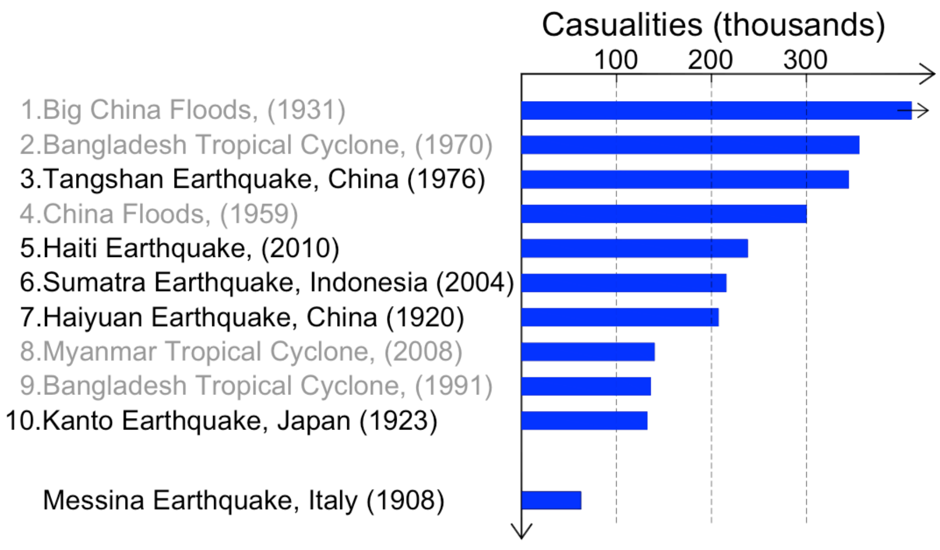
ISTerre @ Université Grenoble-Alpes Grenoble

Ismael Riedel 2015. Analyse de la vulnérabilité du bâti existant – estimation et réduction des incertitudes dans l'estimation des dommages et des pertes pour un scénario sismique donné, Thèse de doctorat Université de Grenoble Alpes.

MAIF FONDATION
Soutenir la recherche
pour prévenir les risques



Sources: Munich Re, IMF, World Bank
UN, EM-DAT disaster database



Sources: UN, USGS, EM-DAT database

Les séismes représentent **15%** des aléas naturels mais produisent **33%** des victimes et des pertes économiques

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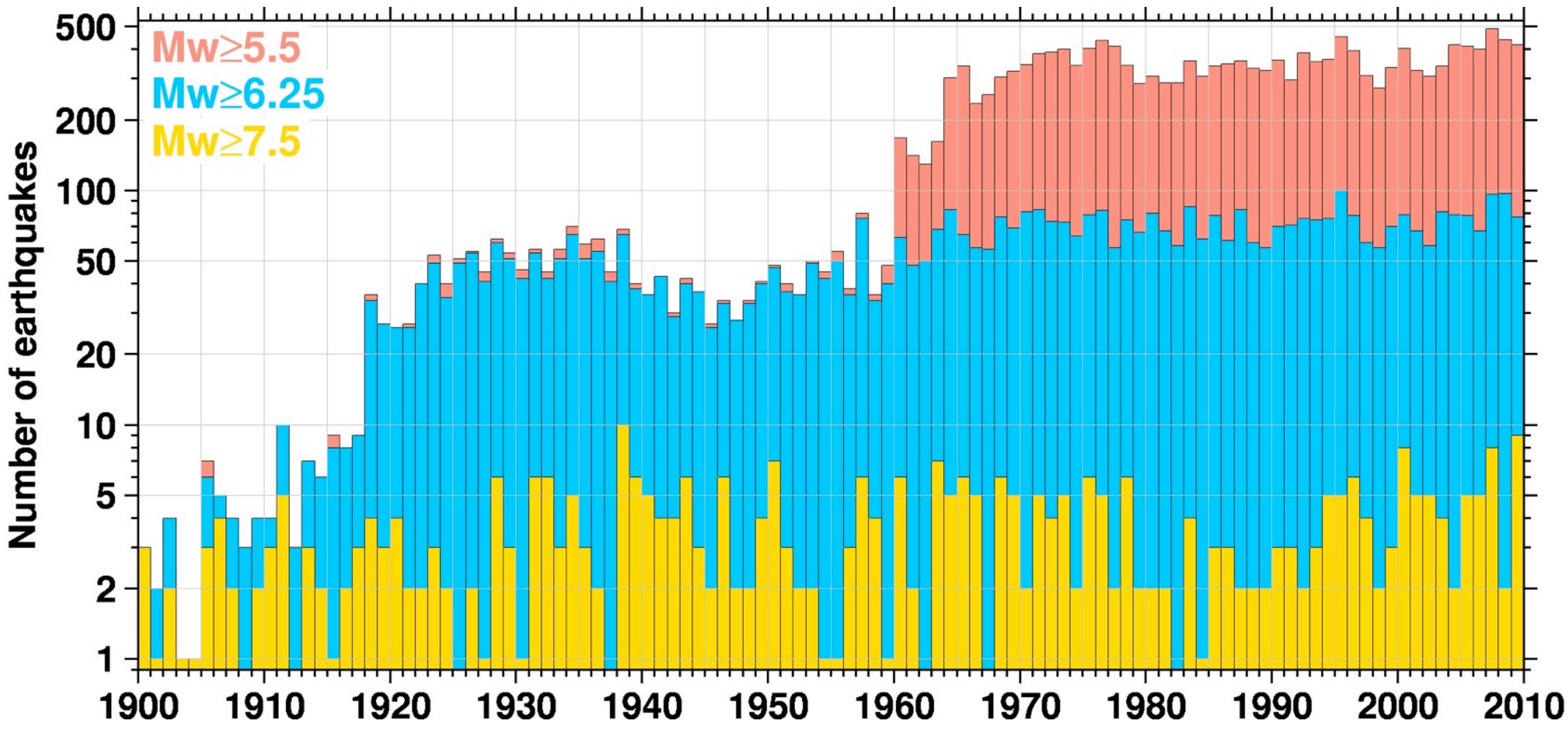
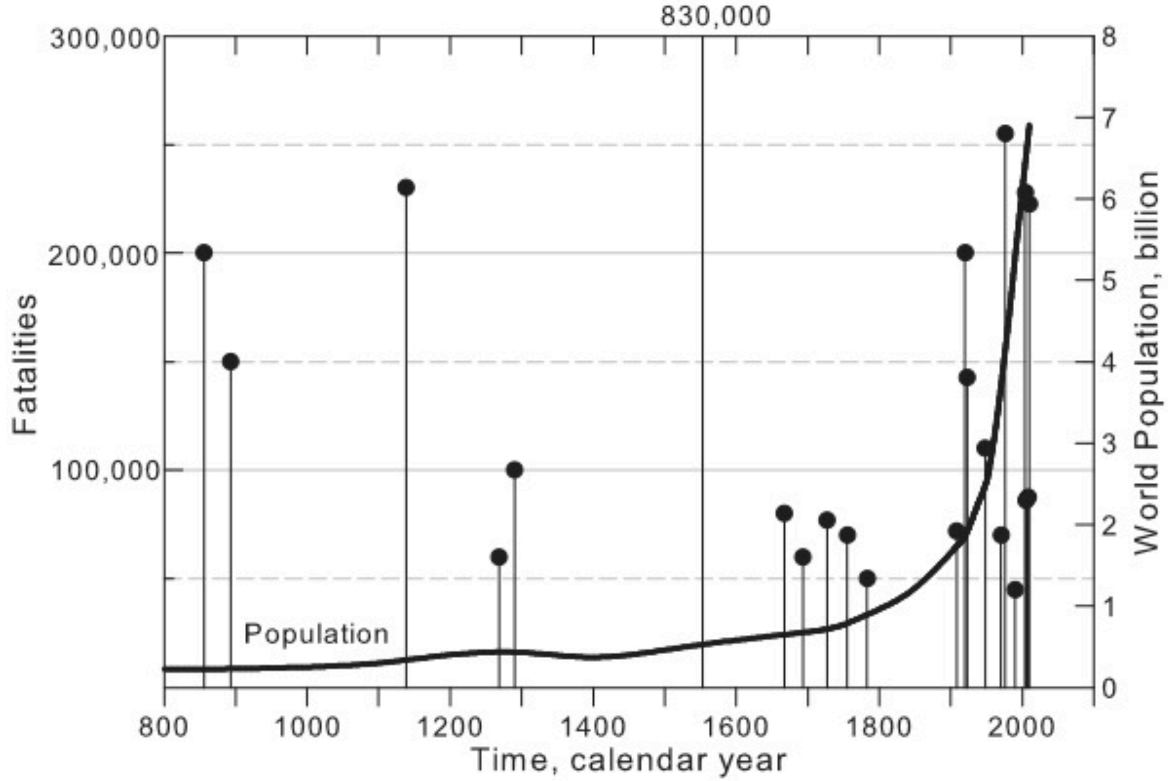
Seismic Hazard - Ground motion produced by the earthquake at one site



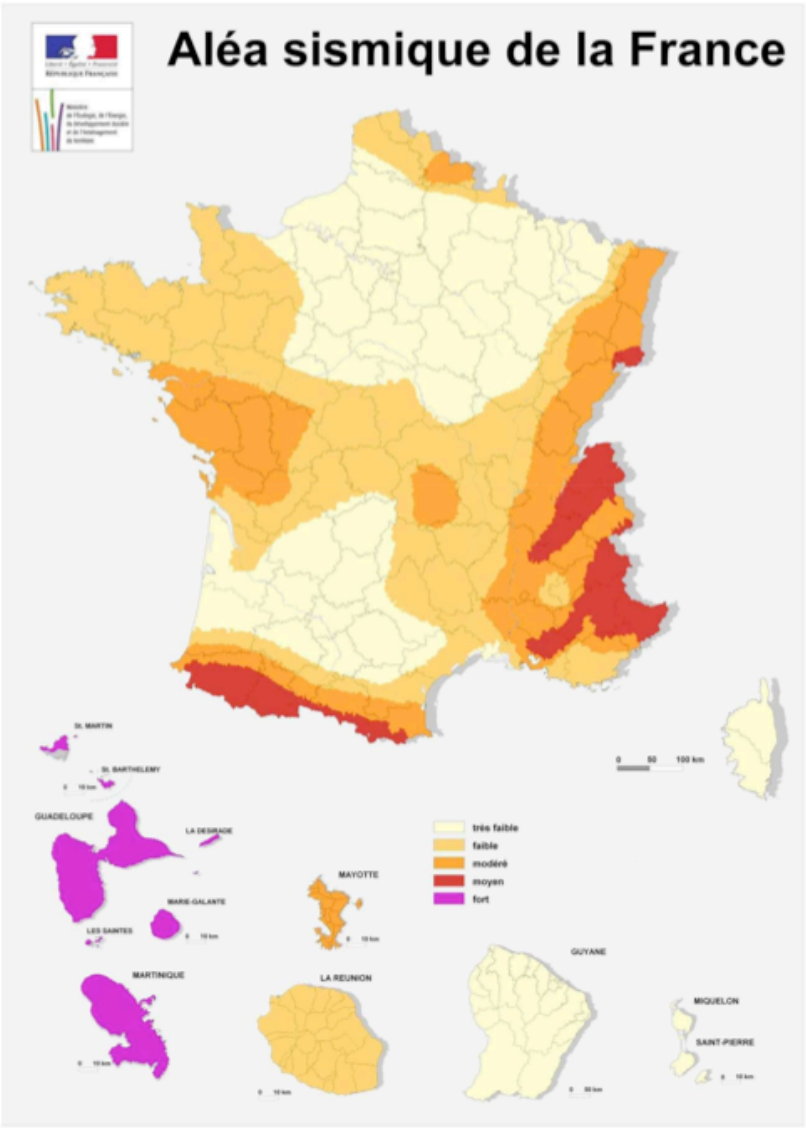
Source: ISC

Seismic risk - Seismic consequences (economic losses and fatalities) for a given ground motion

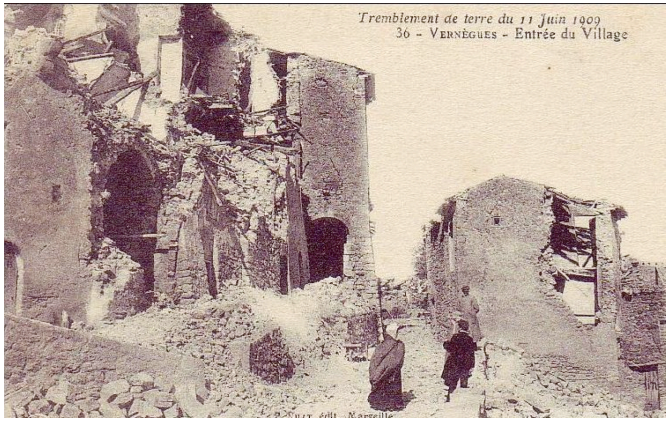


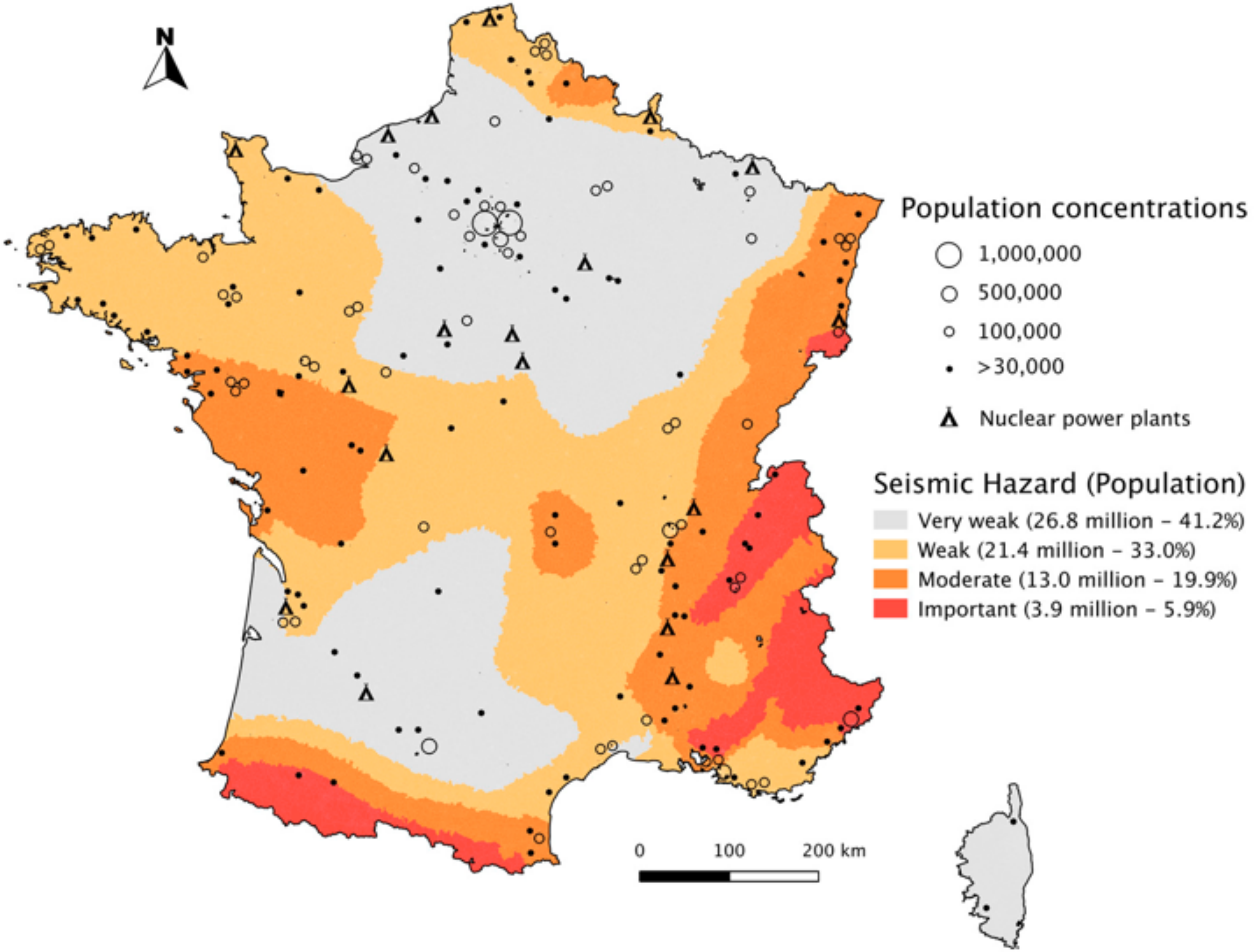
Considering a constant urbanization rate: 2.8 millions of fatalities before 2100

Holzer and Savage, Earthquake Spectra, 2013

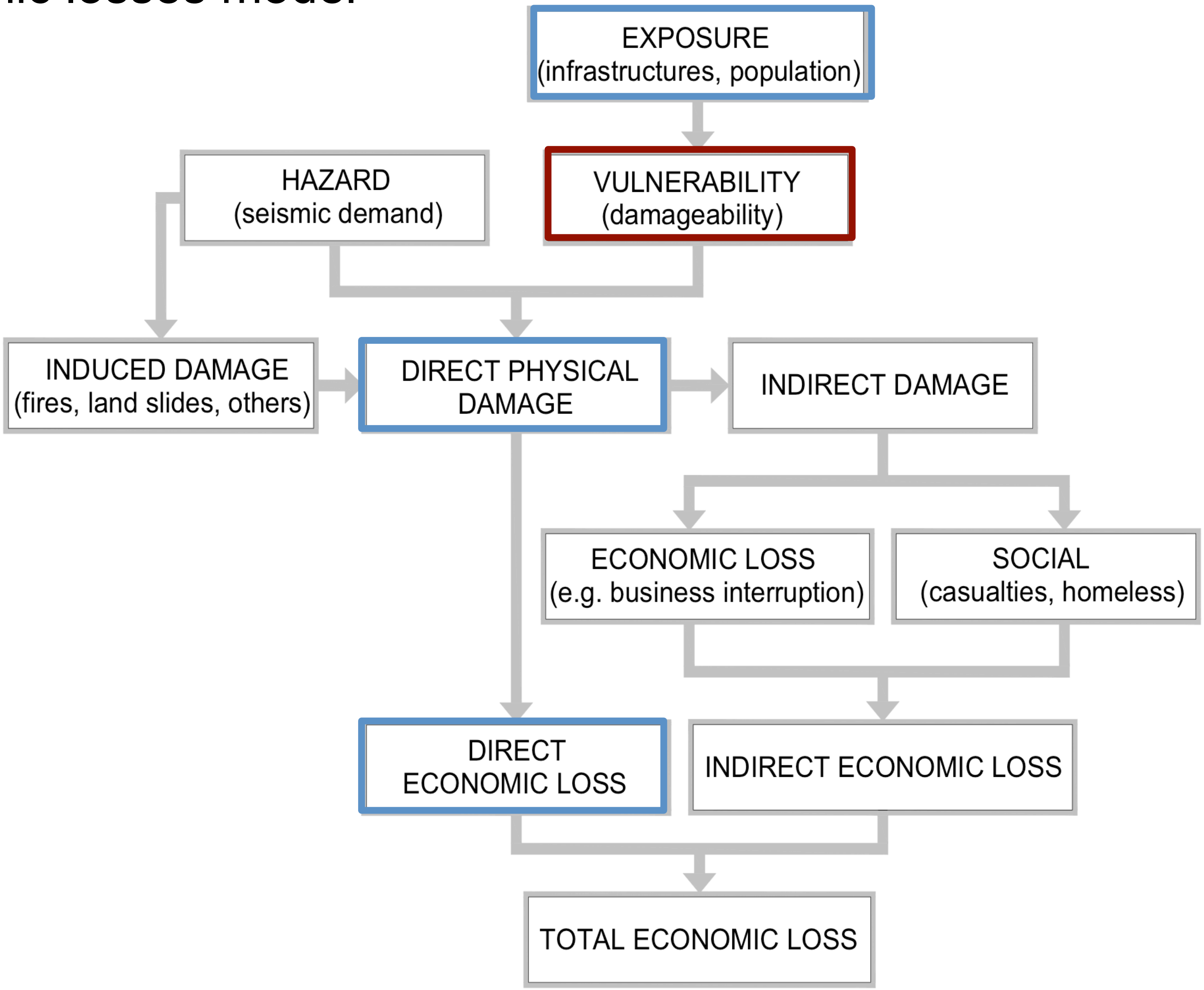


M6 Lambesc Earthquake (1909)




N
Population concentrations
1,000,000
500,000
100,000
>30,000
Nuclear power plants
Seismic Hazard (Population)
Very weak (26.8 million – 41.2%)
Weak (21.4 million – 33.0%)
Moderate (13.0 million – 19.9%)
Important (3.9 million – 5.9%)
0
100
200 km

Seismic losses model



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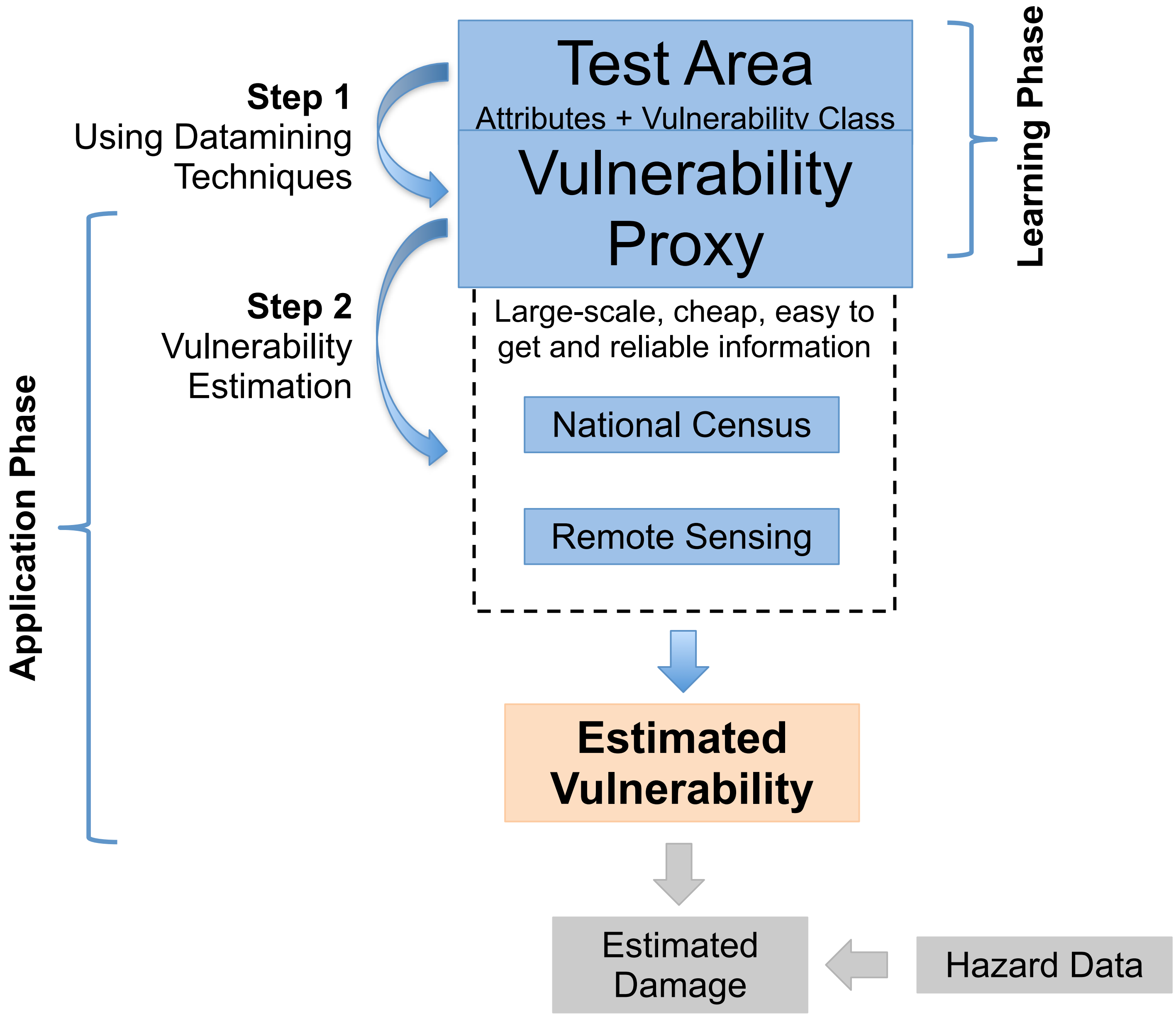
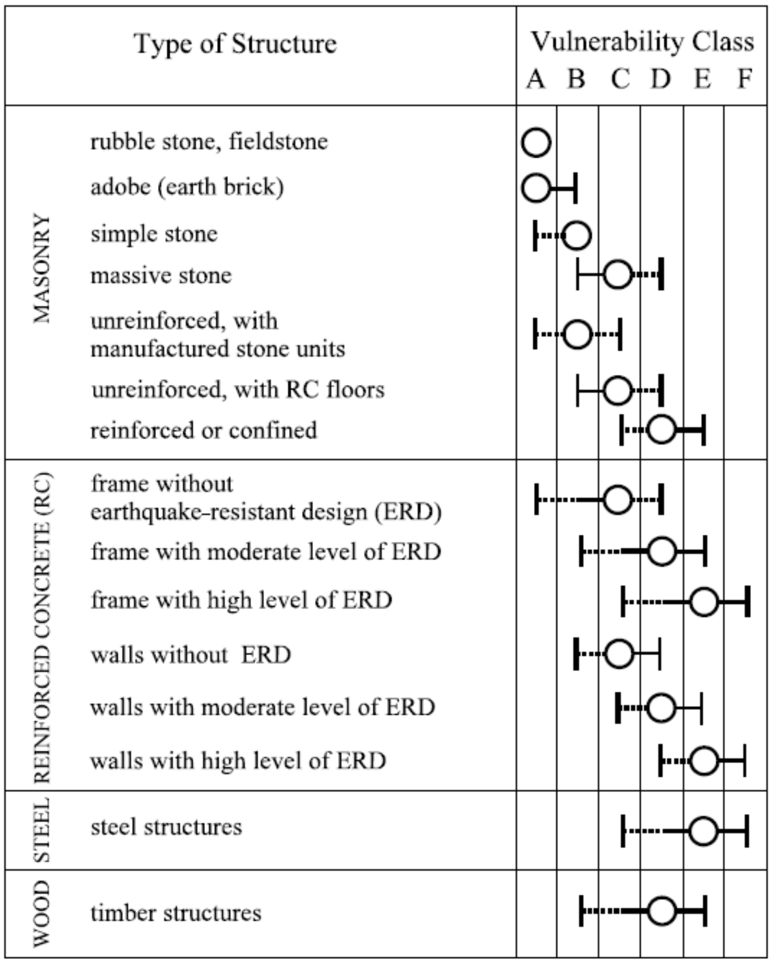


European Macroseismic Scale EMS-98

(Grunthal & Levret, 1998)



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

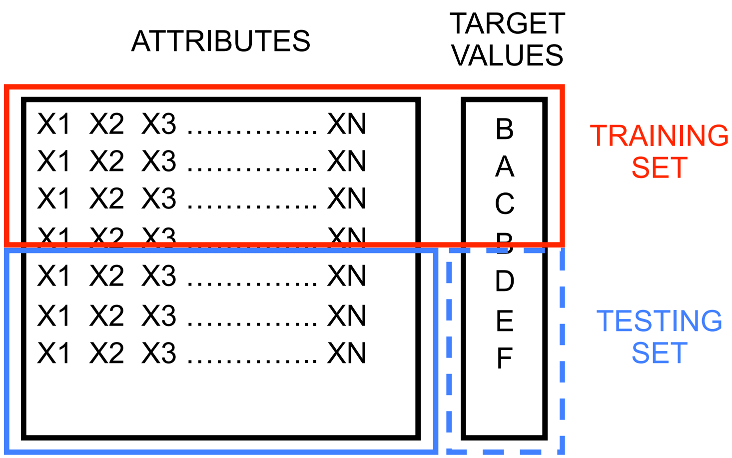
Damage Probability Matrix
Vulnerability Class "A"

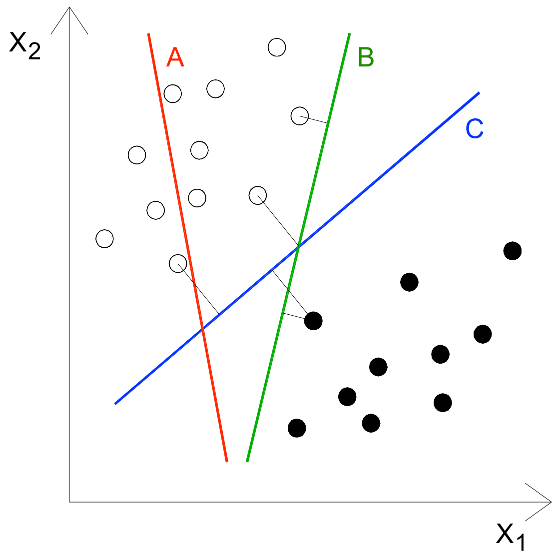
EMS98 Intensity	D0	D1	D2	D3	D4	D5
IV	1.00	0.00	0.00	0.00	0.00	0.00
V	0.95	**0.05**	0.00	0.00	0.00	0.00
VI	0.60	**0.35**	**0.05**	0.00	0.00	0.00
VII	0.05	0.20	0.35	**0.35**	**0.05**	0.00
VIII	0.00	0.05	0.20	0.35	**0.35**	**0.05**
IX	0.00	0.00	0.05	0.25	0.35	**0.35**
X	0.00	0.00	0.00	0.00	0.20	**0.80**
XI	0.00	0.00	0.00	0.00	0.00	1.00
XII	0.00	0.00	0.00	0.00	0.00	1.00

(Lagomarsino & Giovinazzi , 2006)
(Tyagunov et al., 2014)
(Riedel et al., 2014)

Support Vector Machine (SVM) Vapnik et al (1995), Burges (1998), Christianini et al (2000)

Supervised learning models with associated learning algorithms that ANALYSE data and RECOGNIZE patterns, used for CLASSIFICATION.





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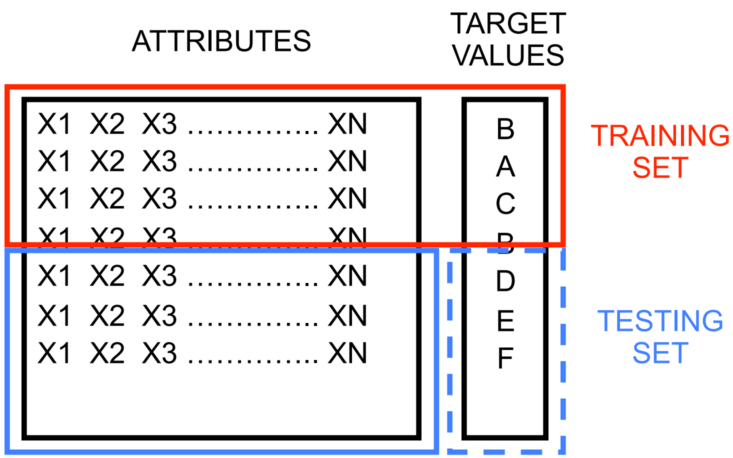

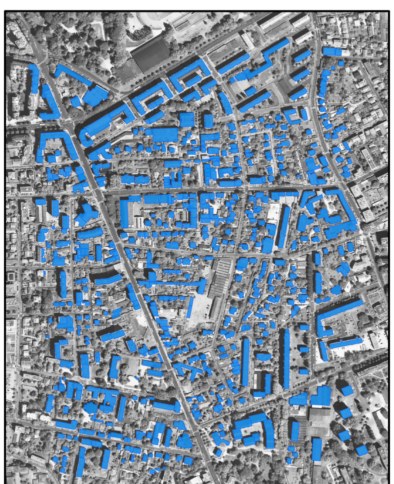

Binary and Linear Classification

Minimize (in **w**, b) ||**w**|| ; subjected to (for any i = 1…n) yi (**w**.**xi** – b) >= 1

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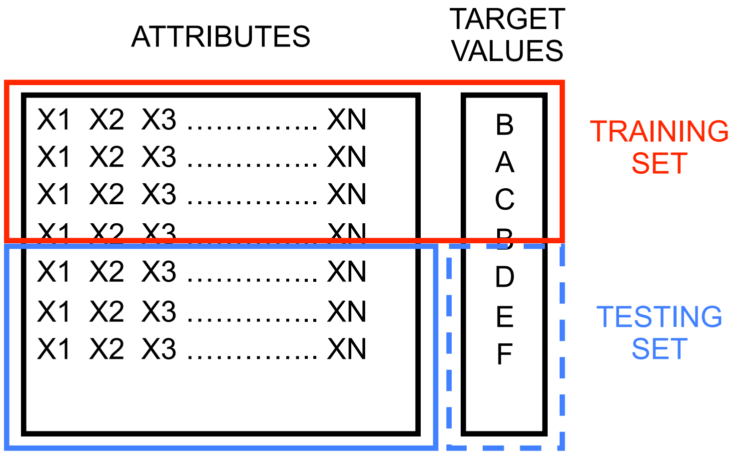

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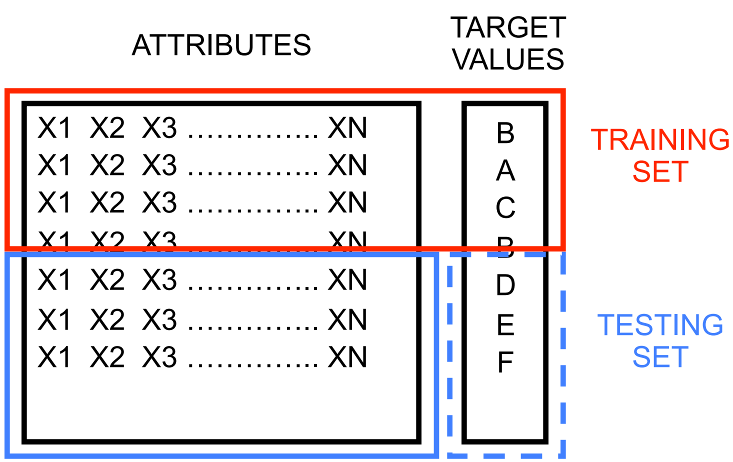

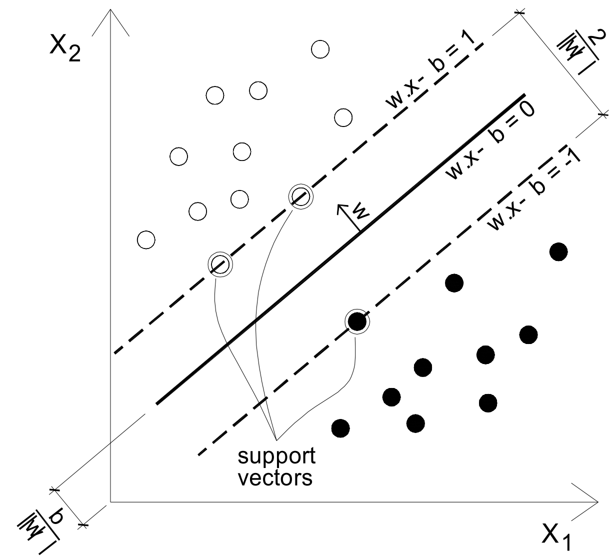

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Support Vector Machine (SVM)

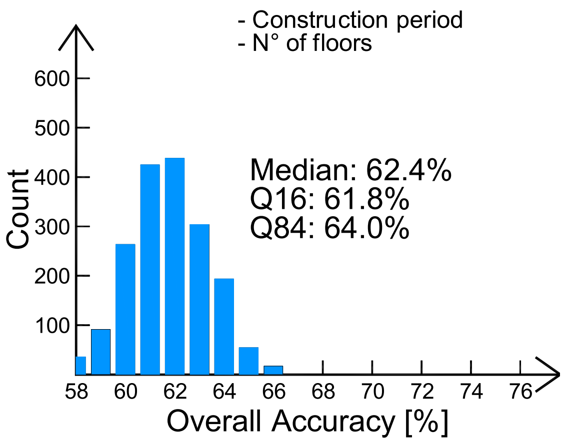
Using Grenoble dataset

30% of Dataset as training set
2 attributes from CENSUS data

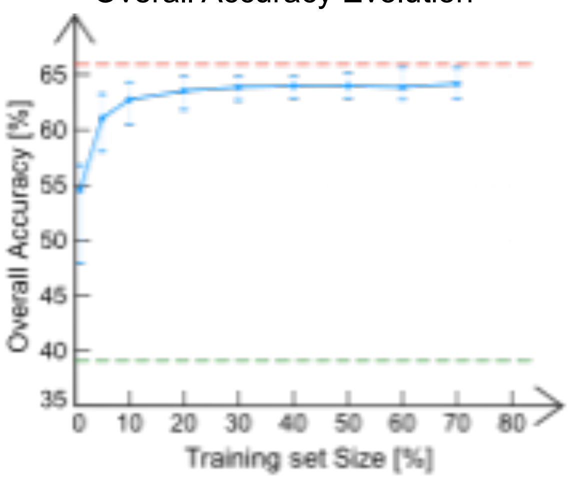
Confusion Matrix

	A	B	C	D	E	F	
A	**131**	121	37	0	0	0	
B	111	**941**	78	21	0	0	
C	29	86	**571**	395	43	0	
D	9	7	107	**249**	193	0	
E	0	0	8	32	**331**	0	
F	0	0	0	0	0	**0**	
	280	1155	801	697	567	0	3500
Acc.	0.629						

Accuracy distribution



Overall Accuracy Evolution



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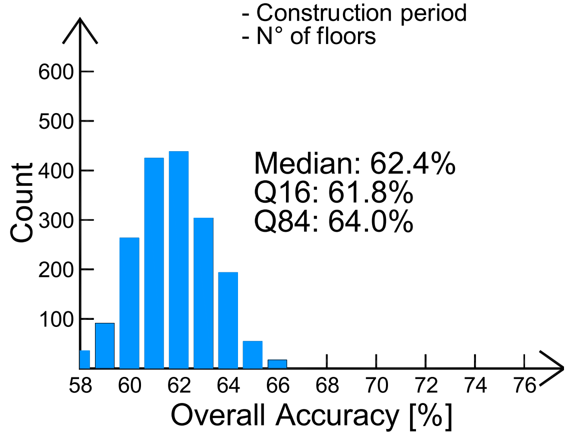

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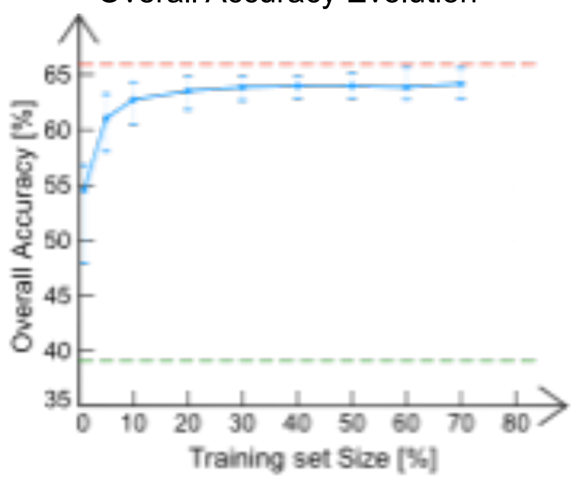

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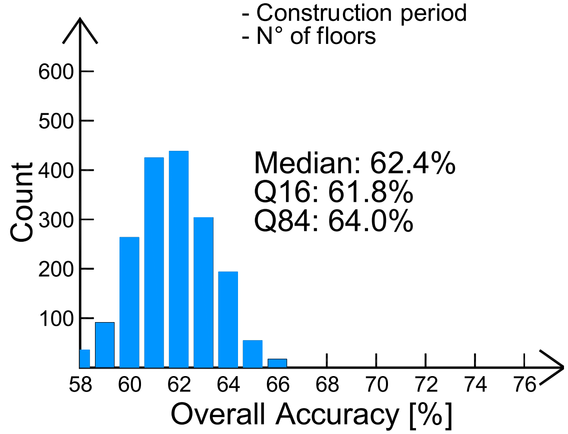

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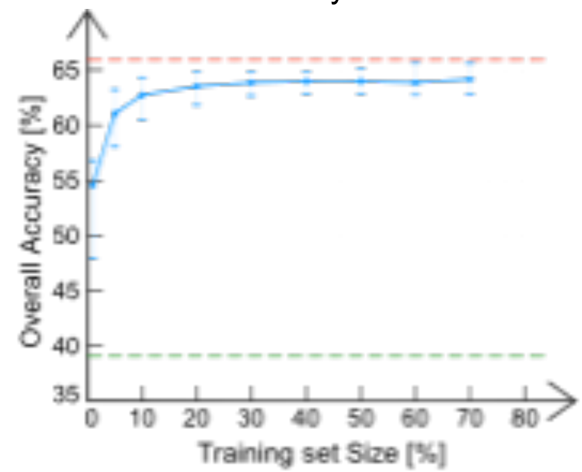
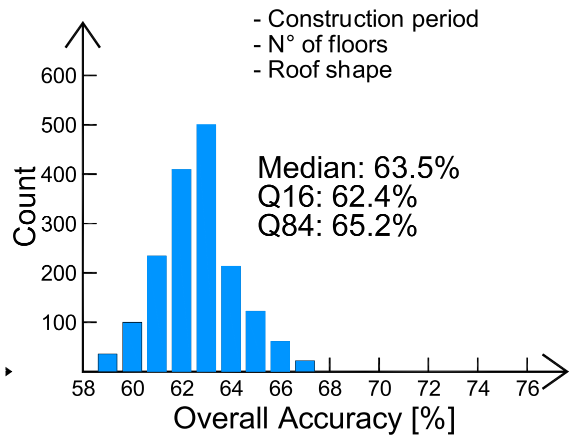
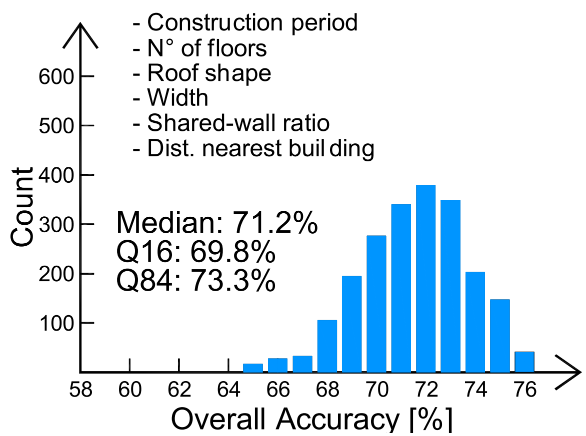


b) 3 attributes - 6 classes



c) 6 attributes - 6 classes



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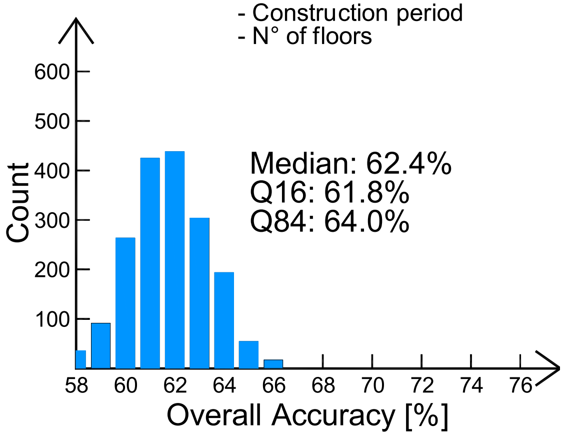

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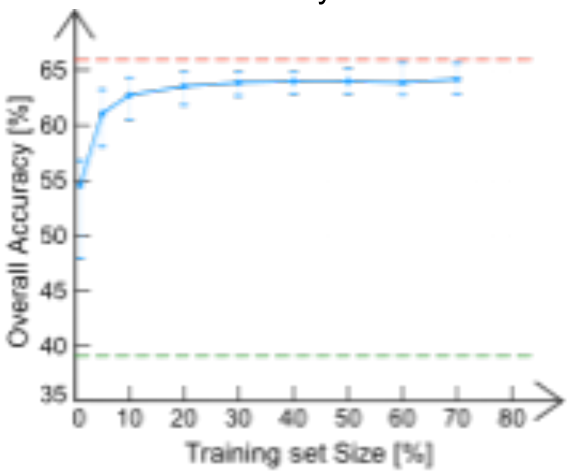

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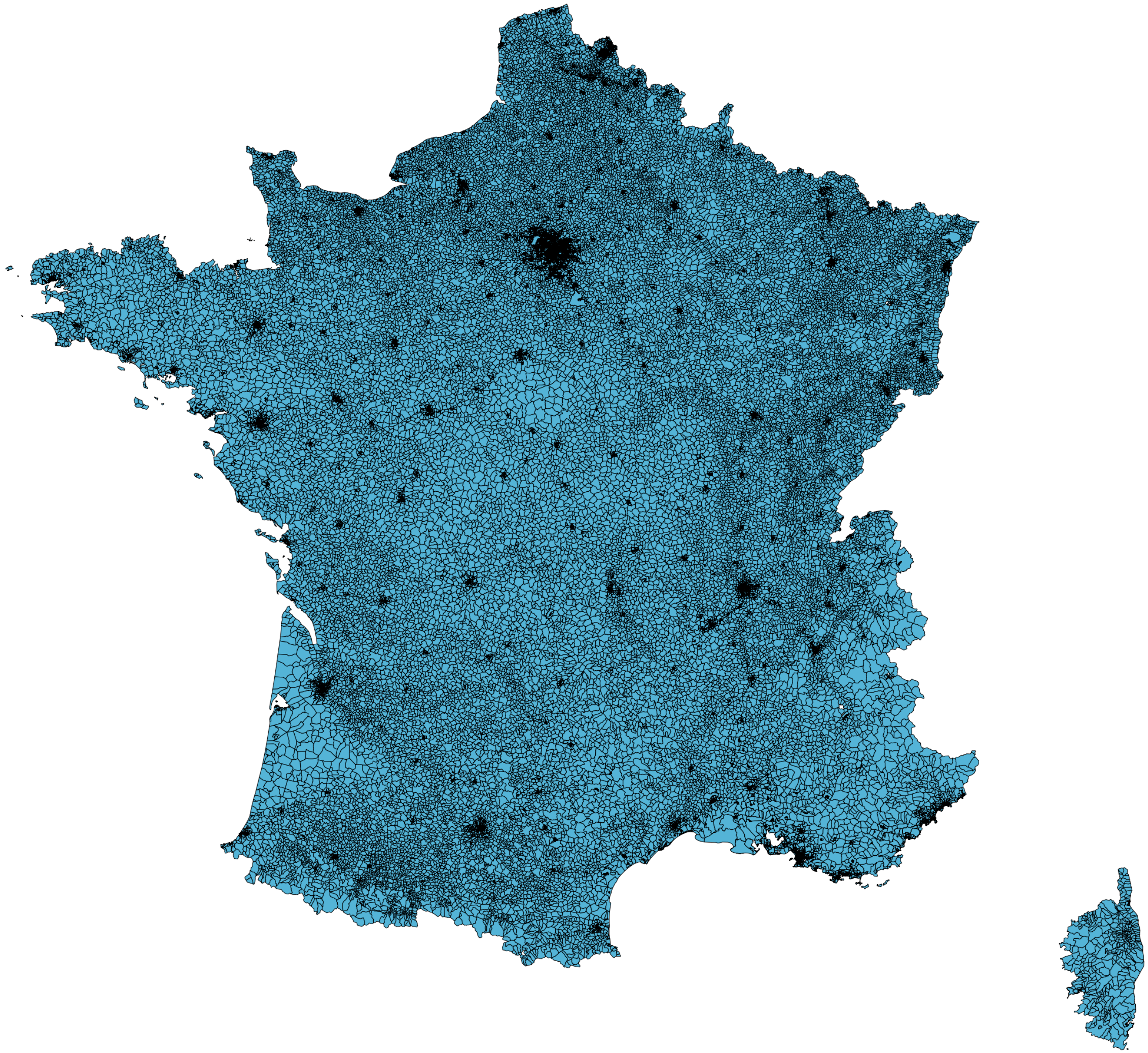
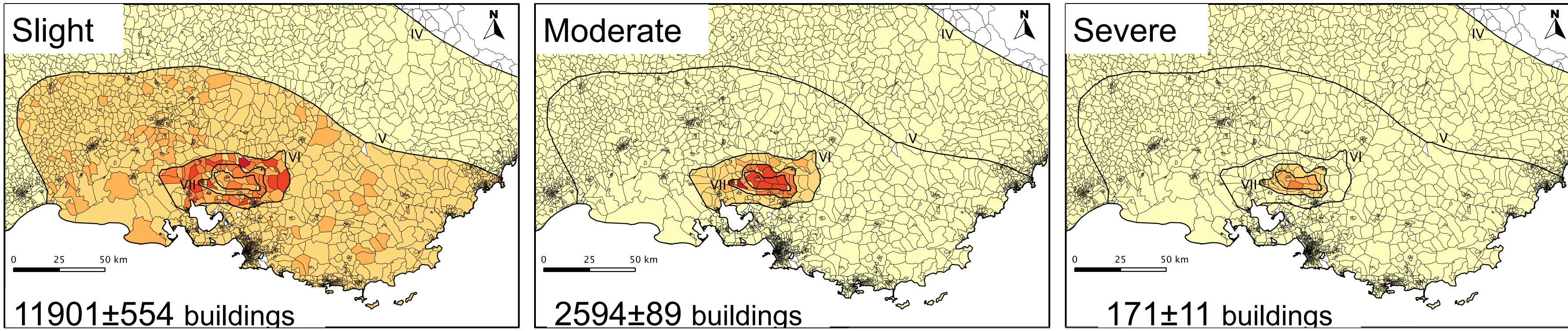


Validation 1 - Lambesc 1909

Lambesc in **1909**



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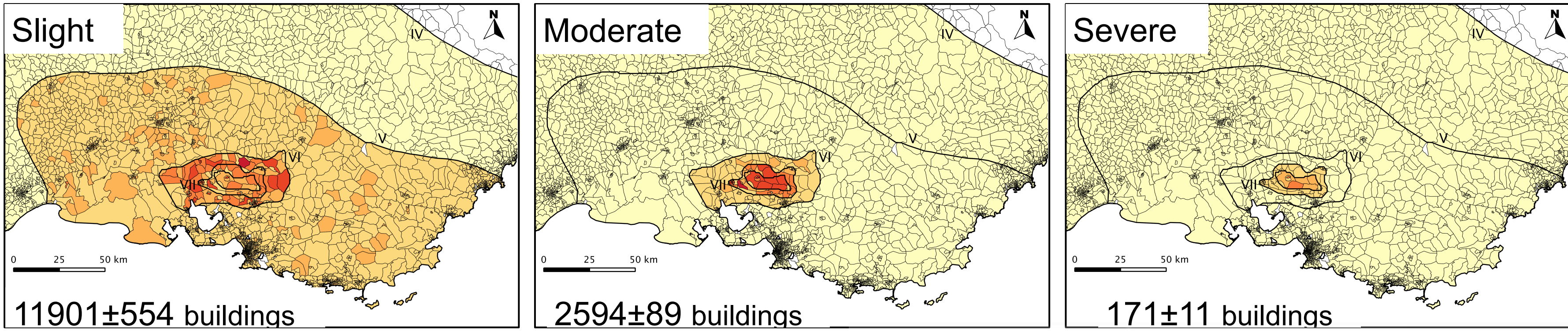
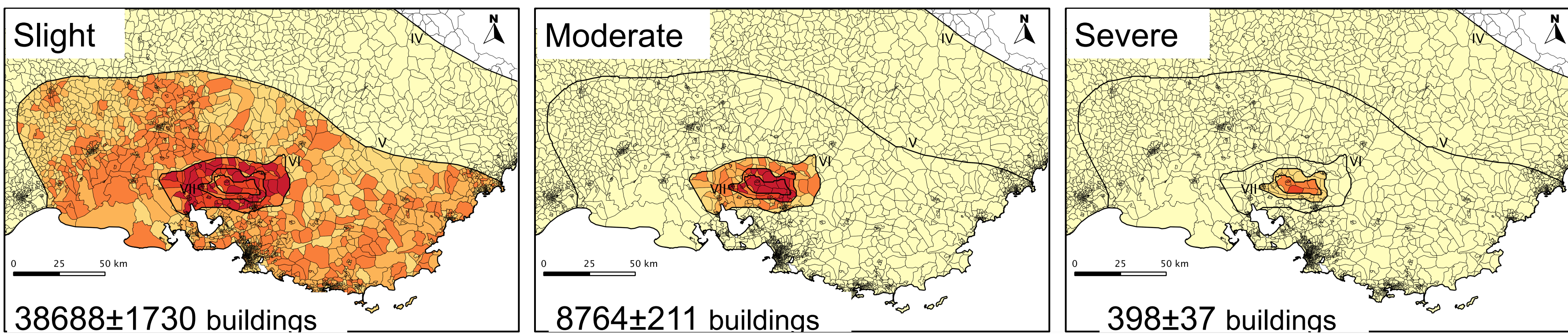


Lambesc in **2008**



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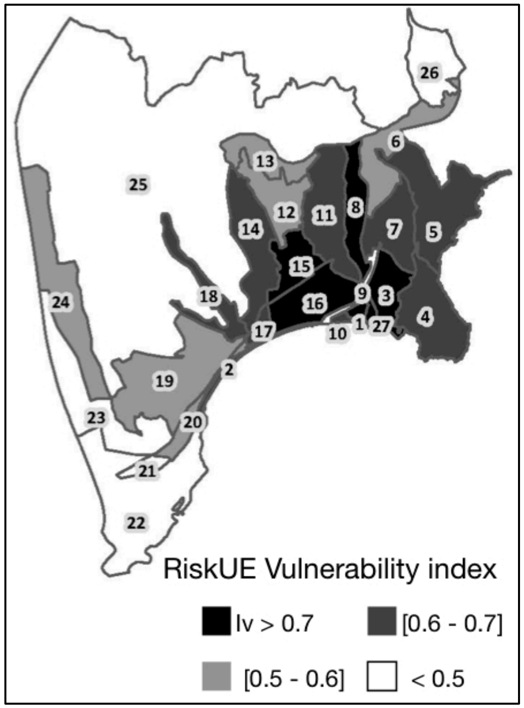
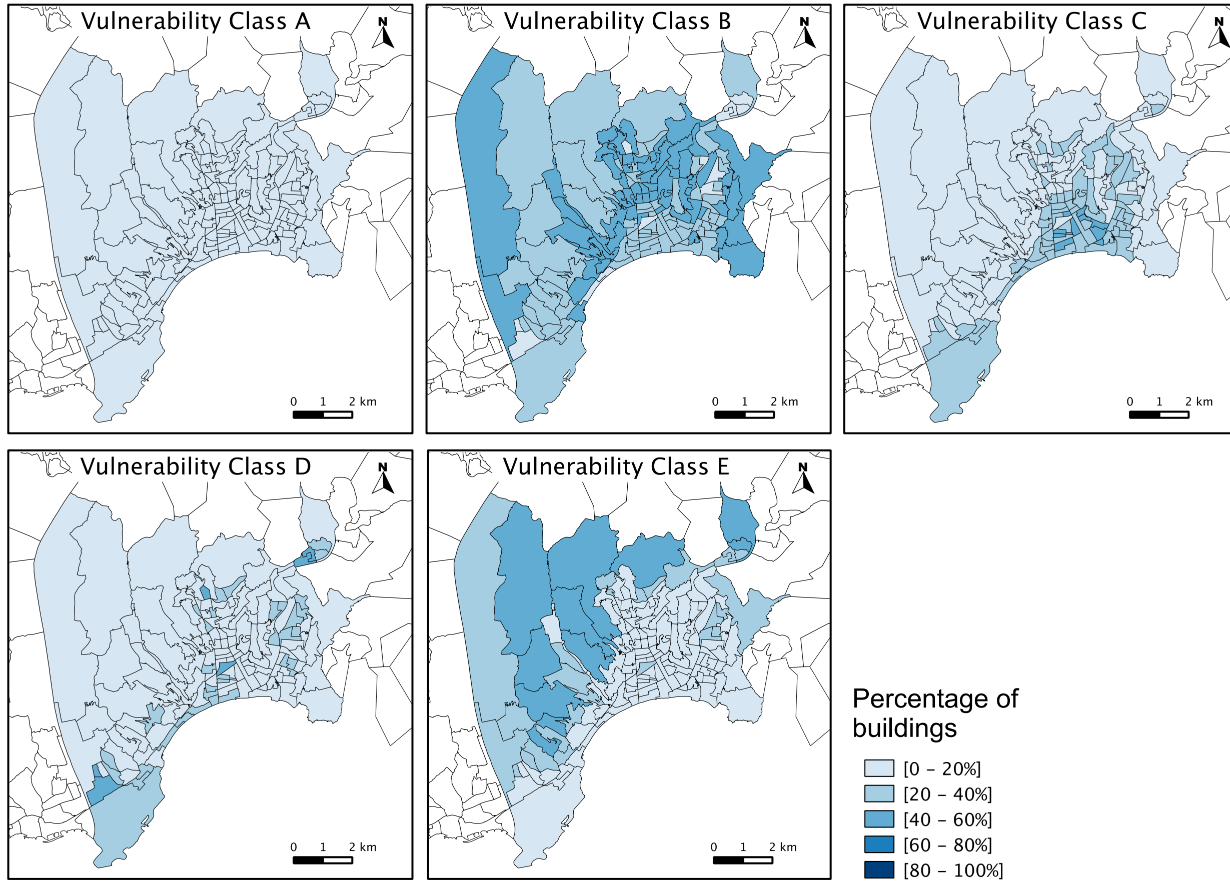
Validation 2 - Nice scenario

RISK-UE



By SVM Proxy



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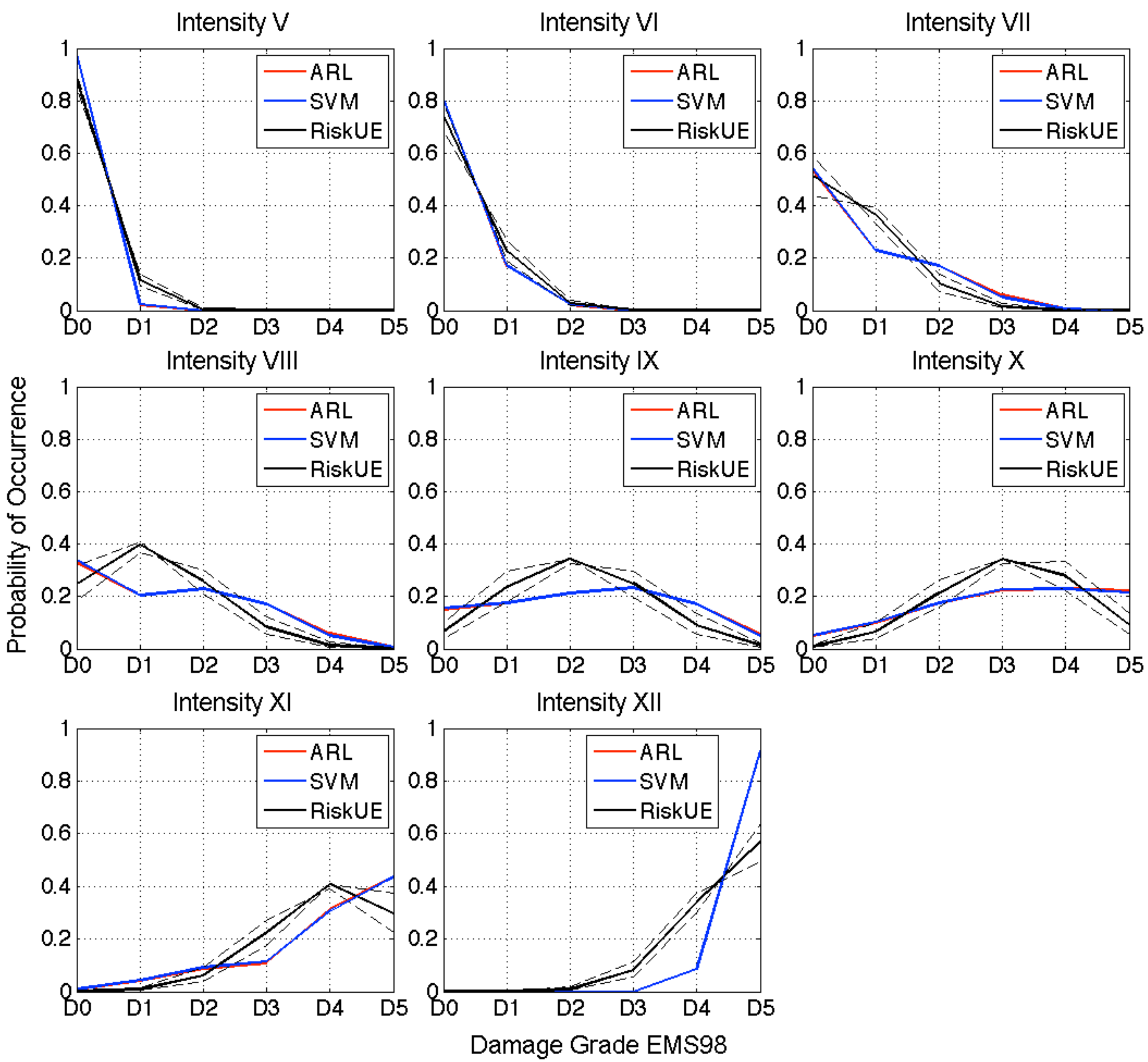
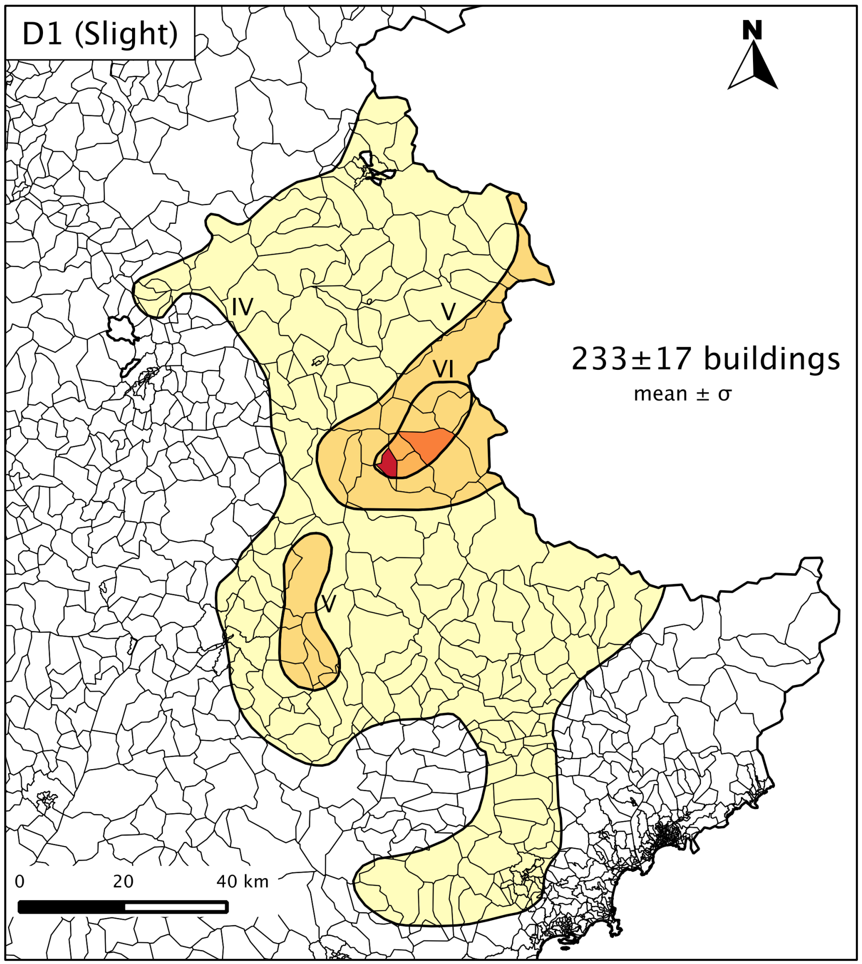
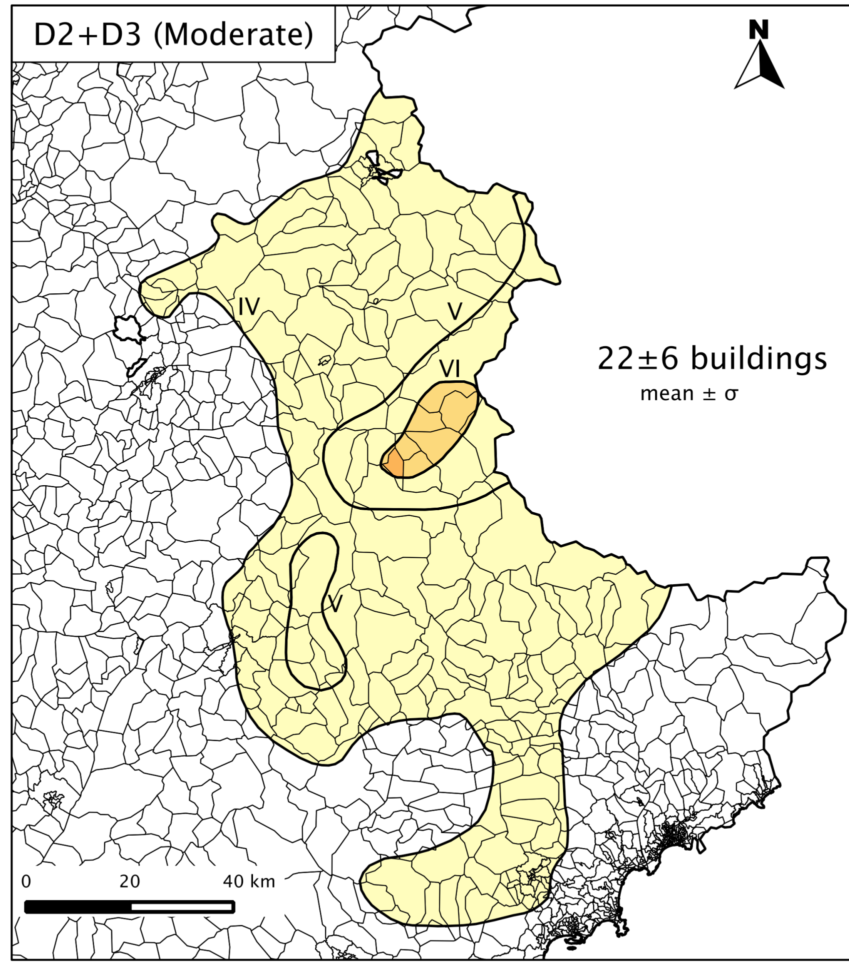


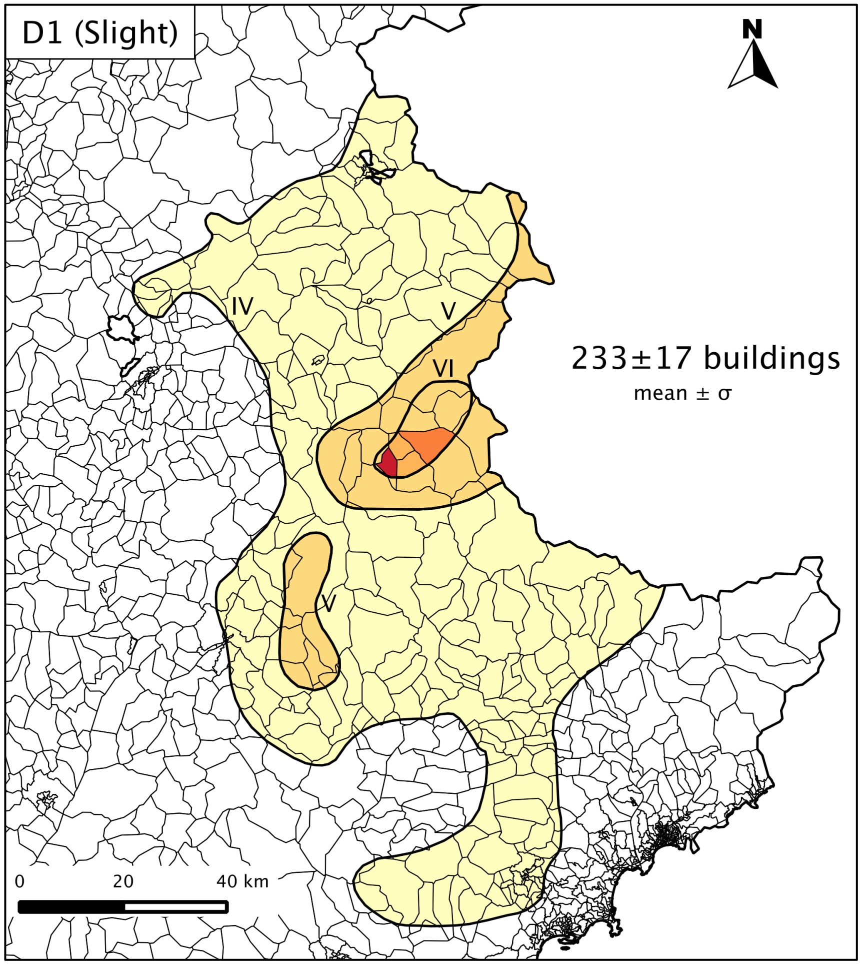
Validation 3 - Ubaye earthquake

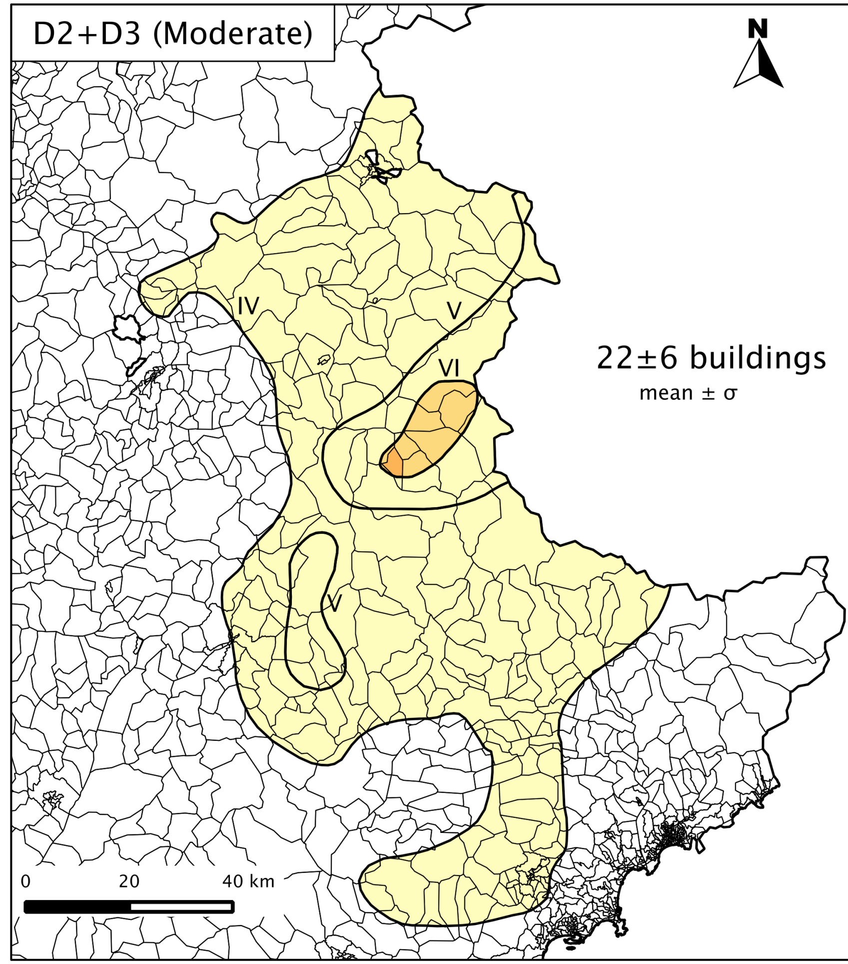




Validation 3 - Ubaye earthquake

Séisme de Barcelonnette (M 4.9 - 2014): 272 bâtiments enfommagés (Source BCSF)





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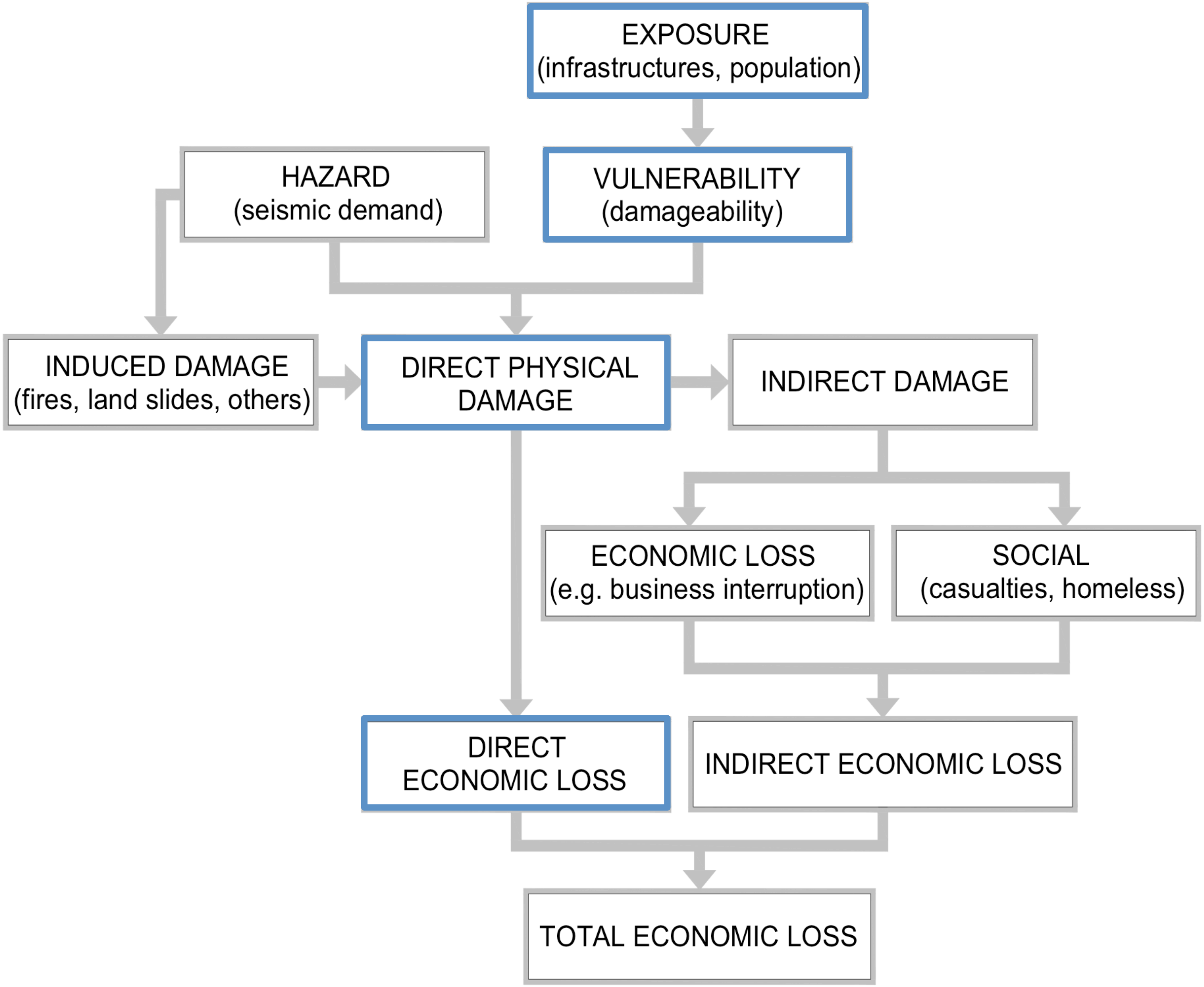
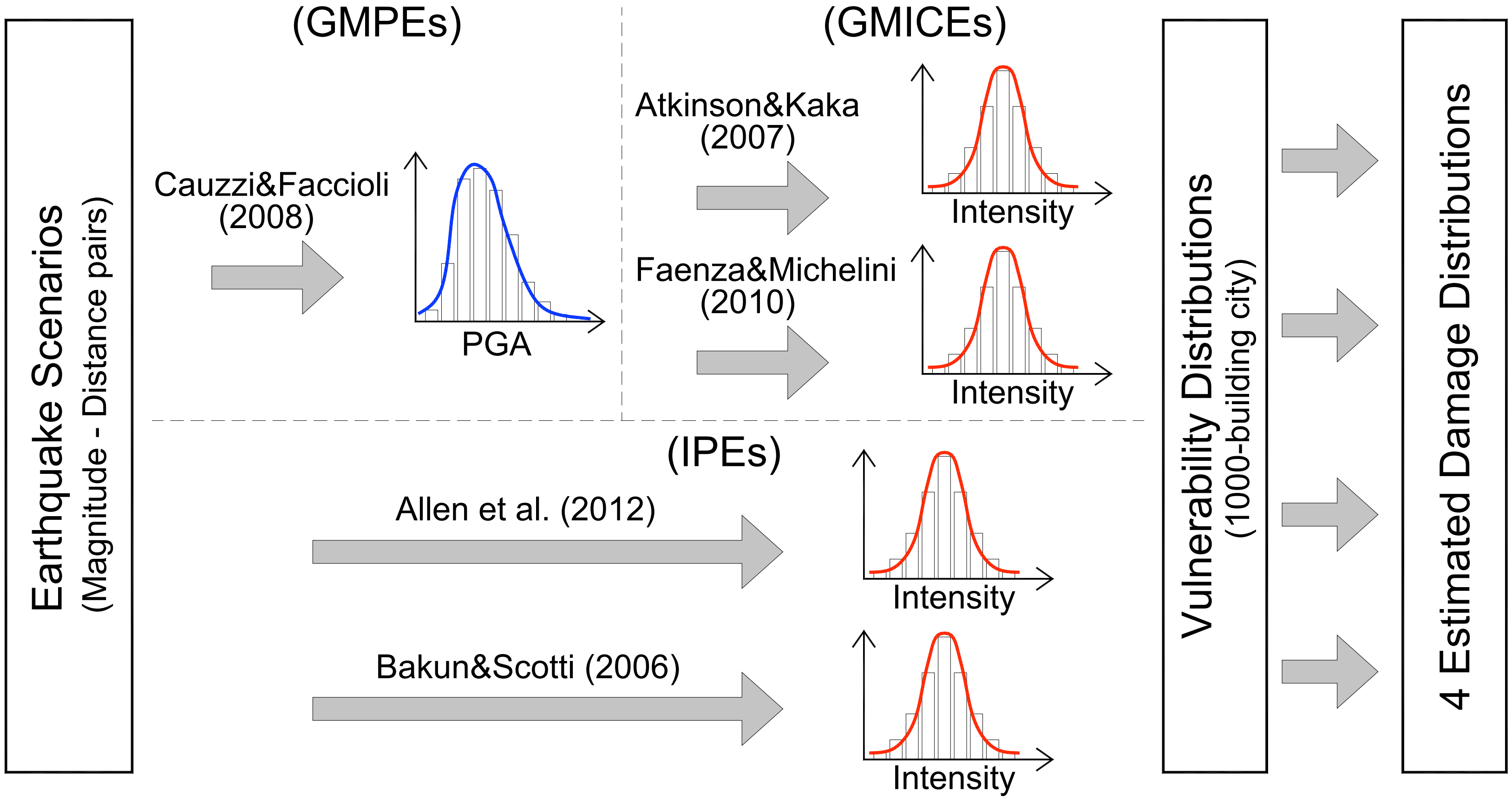


Analyse & quantify uncertainties in the estimation of **Physical Damage**



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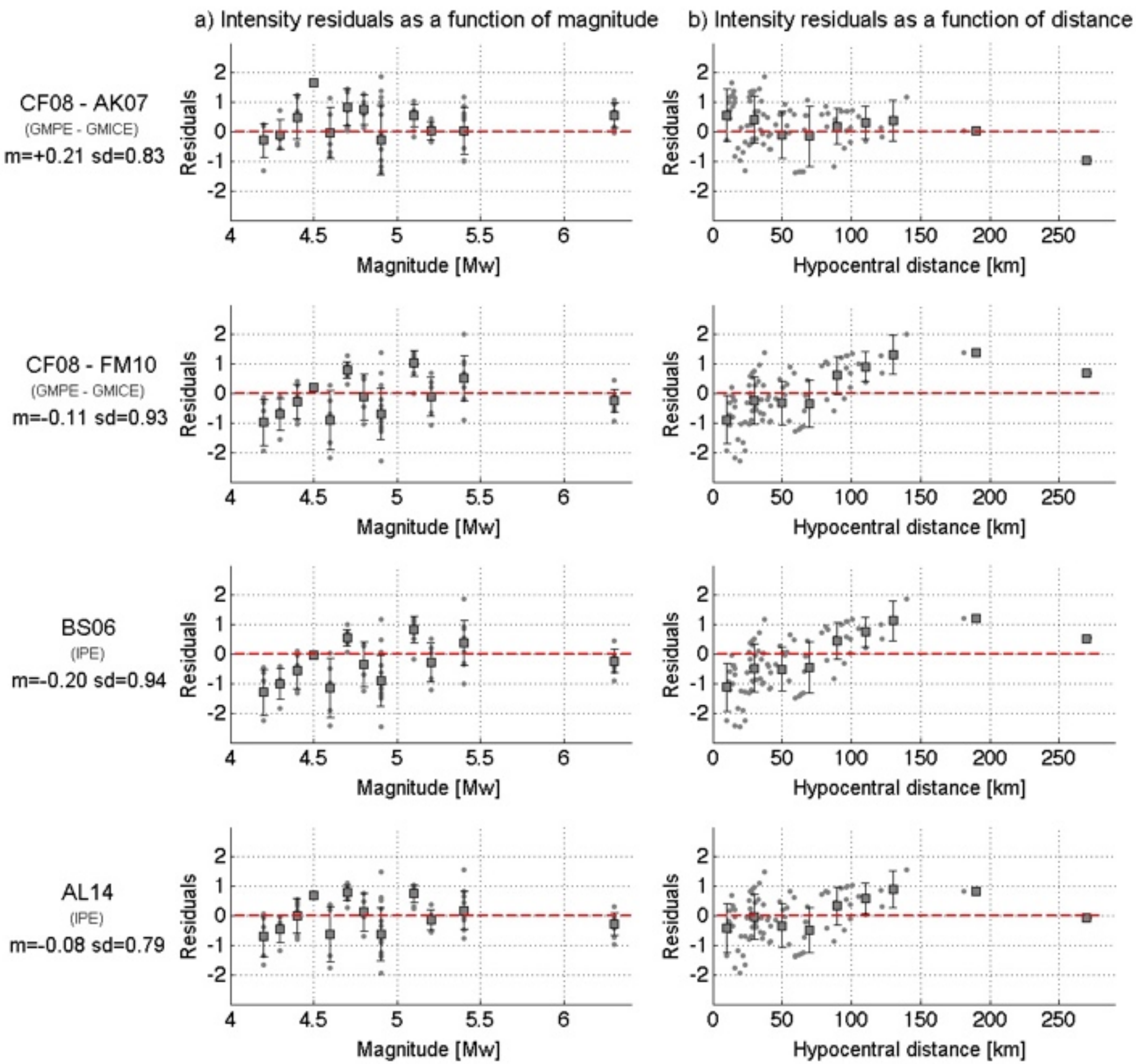
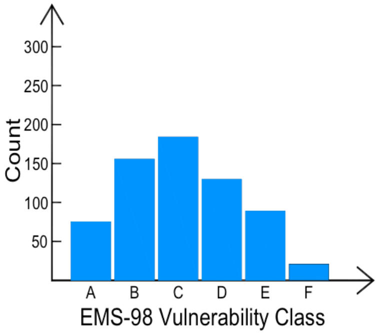
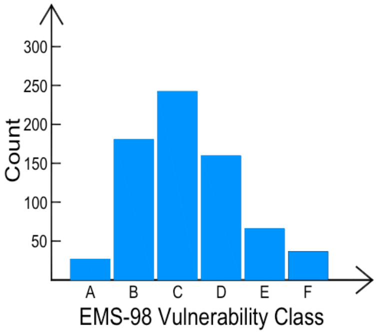


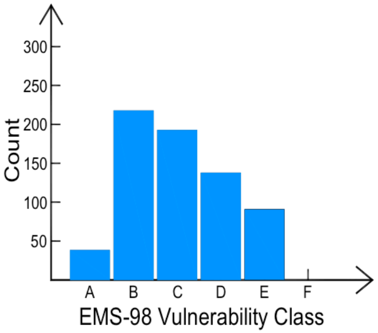
Vulnerability: 1000-Buildings European City like urbanization

	Building typology EMS-98	Percentage	(A)	(B)	(C)	(D)	(E)	(F)
Masonry	Simple stone	5 %	|----	○				
	Massive stone	15 %		|----	○	----|		
	Unreinforced, with manufactured stone units	15 %	|----	○	----|			
	Unreinforced, with reinforced concrete floors	20 %		|----	○	----|		
	Reinforced or confined	5 %			|----	○	----|	
Reinforced concrete	Frame without ERD	10 %	|----	|----	○	----|		
	Frame with moderate level of ERD	7 %		|----	|----	○	----|	
	Frame with high level of ERD	3 %			|----	|----	○	----|
	Walls without ERD	10 %		|----	○	----|		
	Walls with moderate level of ERD	7 %			|----	○	----|	
	Walls with high level of ERF	3 %				|----	○	----|

○ most likely vulnerability class; (more than 70%) |---- probable range; (less than 30%) |---- range of less probable, exceptional cases (less than 5%)







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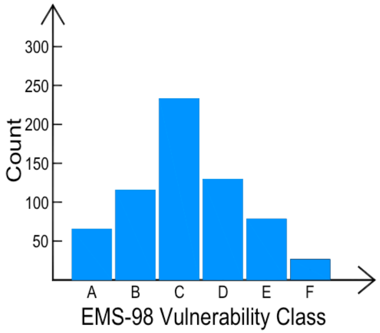
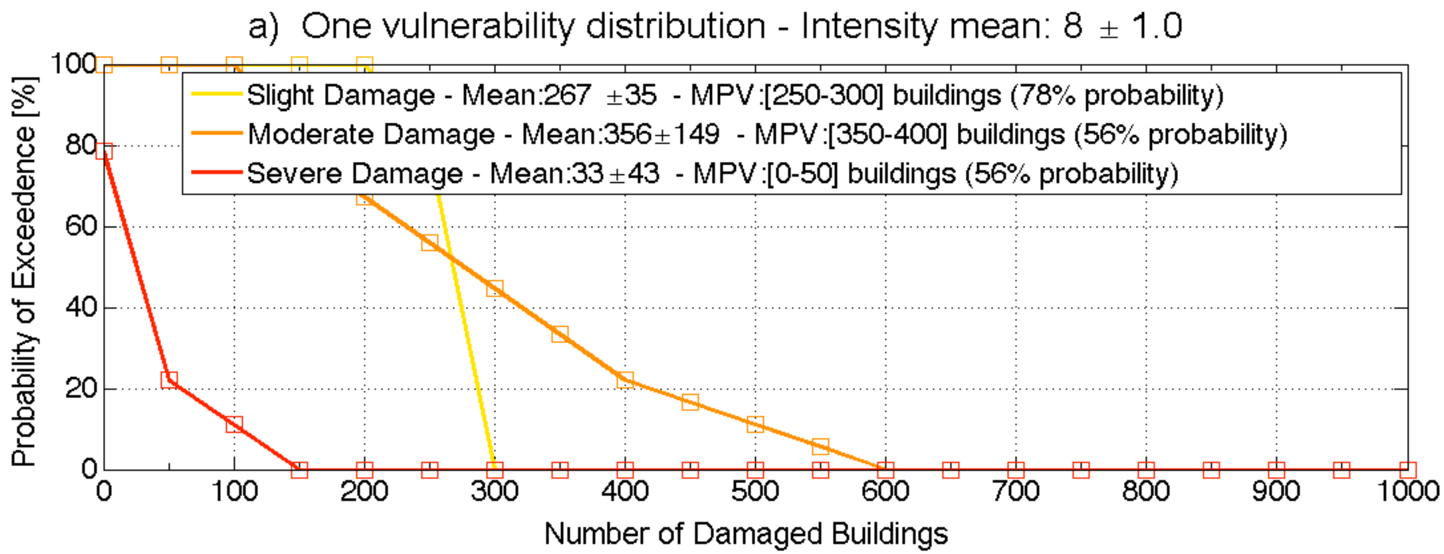
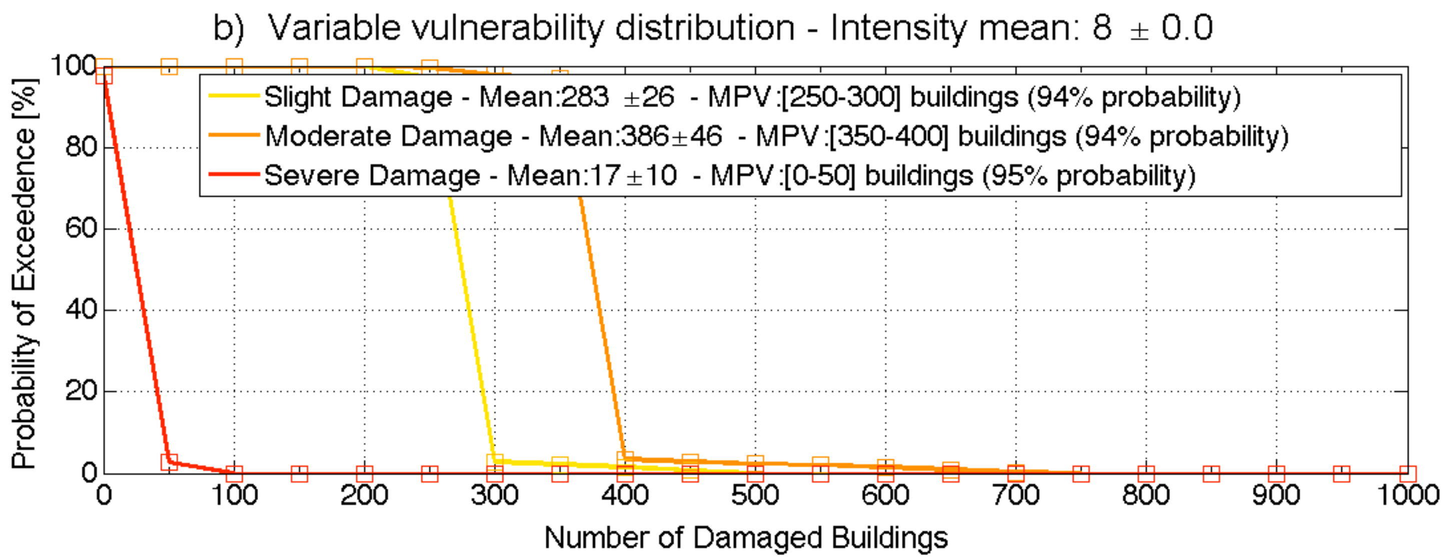


Damage Estimations: Global Uncertainty

Sensitivity Analysis for different sources of uncertainty





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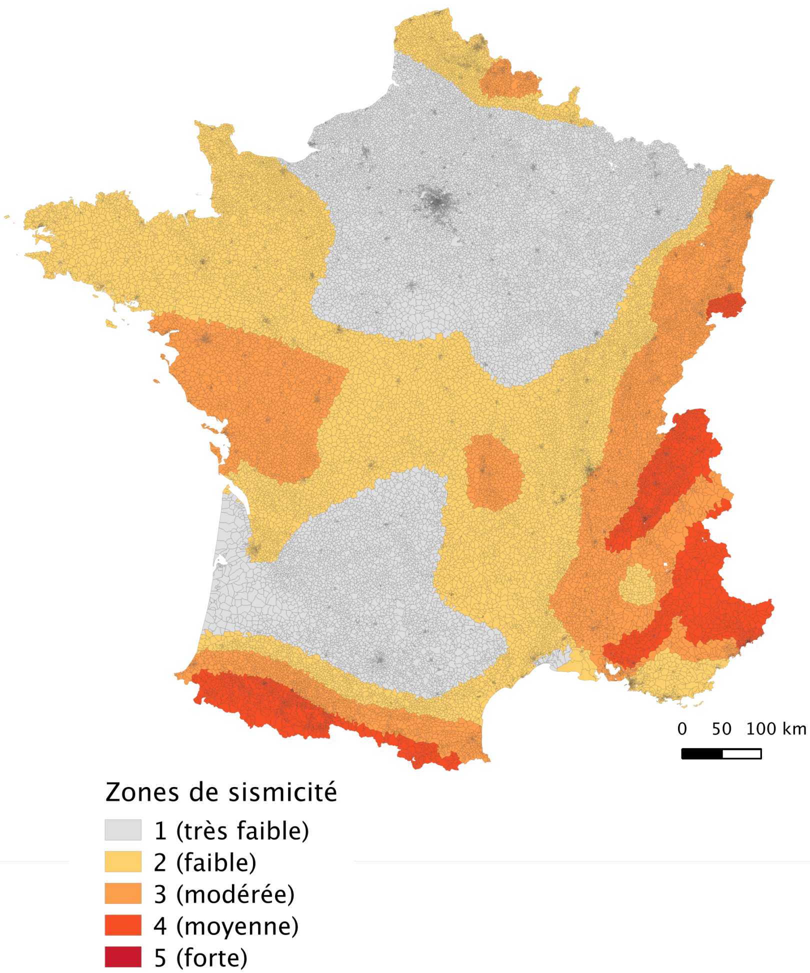
pour prévenir les risques

Carte Nationale réglementaire

Zonage sismique de la France
en vigueur depuis le 1er mai 2011
(art. D. 563-8-1 du code de l'environnement)



Seismic Zone	Level of hazard	Accelerations (rock site) [cm/s²] R_T 475 years (10% in 50 years)	R_T 95 years (10% in 10 years)	R_T 47 years (10% in 5 years)
1	Very weak	40.0	25.0	21.4
2	Weak	70.0	43.8	37.5
3	Moderate	110.0	68.8	58.9
4	Important	160.0	100.00	85.7
5	Strong	300.0	187.51	160.7

EN 1998-1 (CEN, 2005)

$$P_R = 1 - e^{-\frac{T}{R_T}}$$

$$\gamma \approx \left(\frac{P}{P_R}\right)^{-1/k}$$

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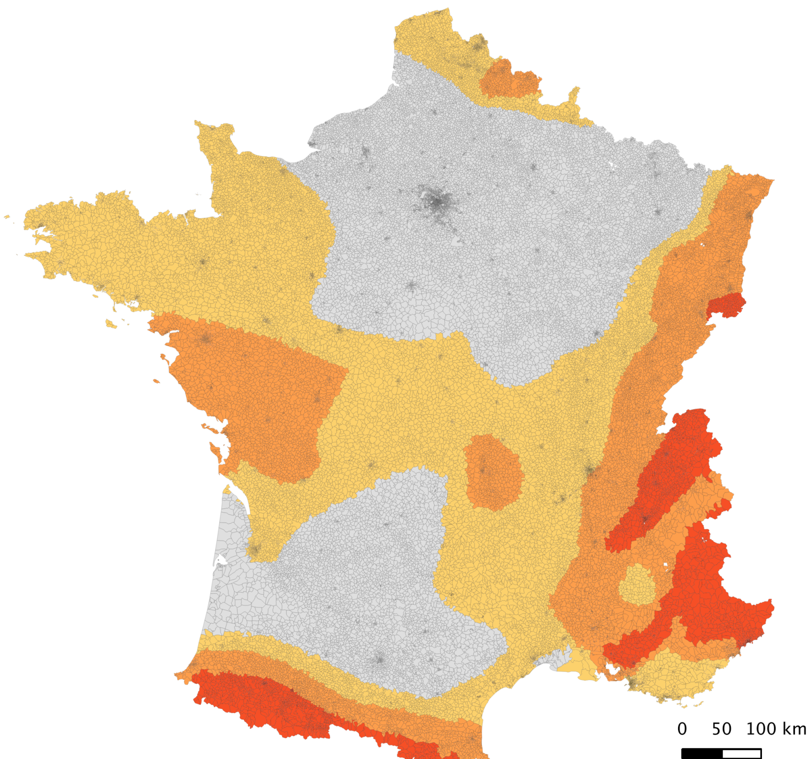
Carte Nationale réglementaire

Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE

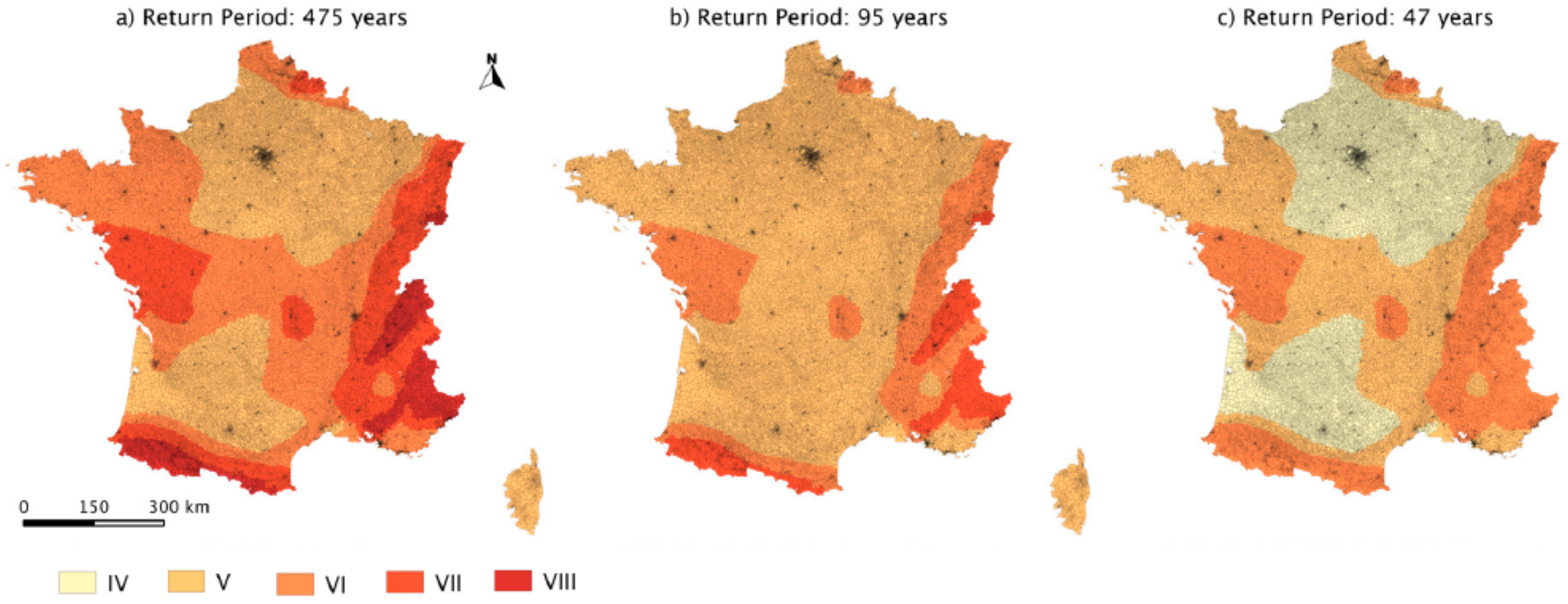
Zonage sismique de la France
en vigueur depuis le 1er mai 2011
(art. D. 563-8-1 du code de l'environnement)



Seismic Zone	Level of hazard	Accelerations (rock site) [cm/s²] R_T 475 years (10% in 50 years)	R_T 95 years (10% in 10 years)	R_T 47 years (10% in 5 years)
1	Very weak	40.0	25.0	21.4
2	Weak	70.0	43.8	37.5
3	Moderate	110.0	68.8	58.9
4	Important	160.0	100.00	85.7
5	Strong	300.0	187.51	160.7

Allen et al., 2014

Seismic Zone	Level of hazard	Calculated Intensities for different accelerations levels R_T 475 years (10% in 50 years)	R_T 95 years (10% in 10 years)	R_T 47 years (10% in 5 years)
1	Very weak	V	V	IV
2	Weak	VI	V	V
3	Moderate	VII	VI	VI
4	Important	VIII	VII	VI


a) Return Period: 475 years
b) Return Period: 95 years
c) Return Period: 47 years
N
0
150
300 km
IV
V
VI
VII
VIII

Estimation des pertes économiques depuis les dommages

Model for Greece (Kappos et al., 2006)
Model for Italy (Di Pascuale & Goretti, 2001)
Model for California (FEMA 443, 2003)

Loss model for Europe (France)

	Damage state label	Central index (%)
All structures types	D0 - None	0.0
	D1 - Slight	3.0
	D2 - Moderate	14.0
	D3 - Substantial to heavy	34.0
	D4 - Very heavy	65.0
	D5 - Destruction	90.0

$$C^{direct} = \sum_{i=1}^{i=5} P_{Di} * C_{Di}$$

Mean Direct Loss
(% of total building stock value)

Percentage of buildings
(with damage Di)

Loss Ratio
(for damage Di)

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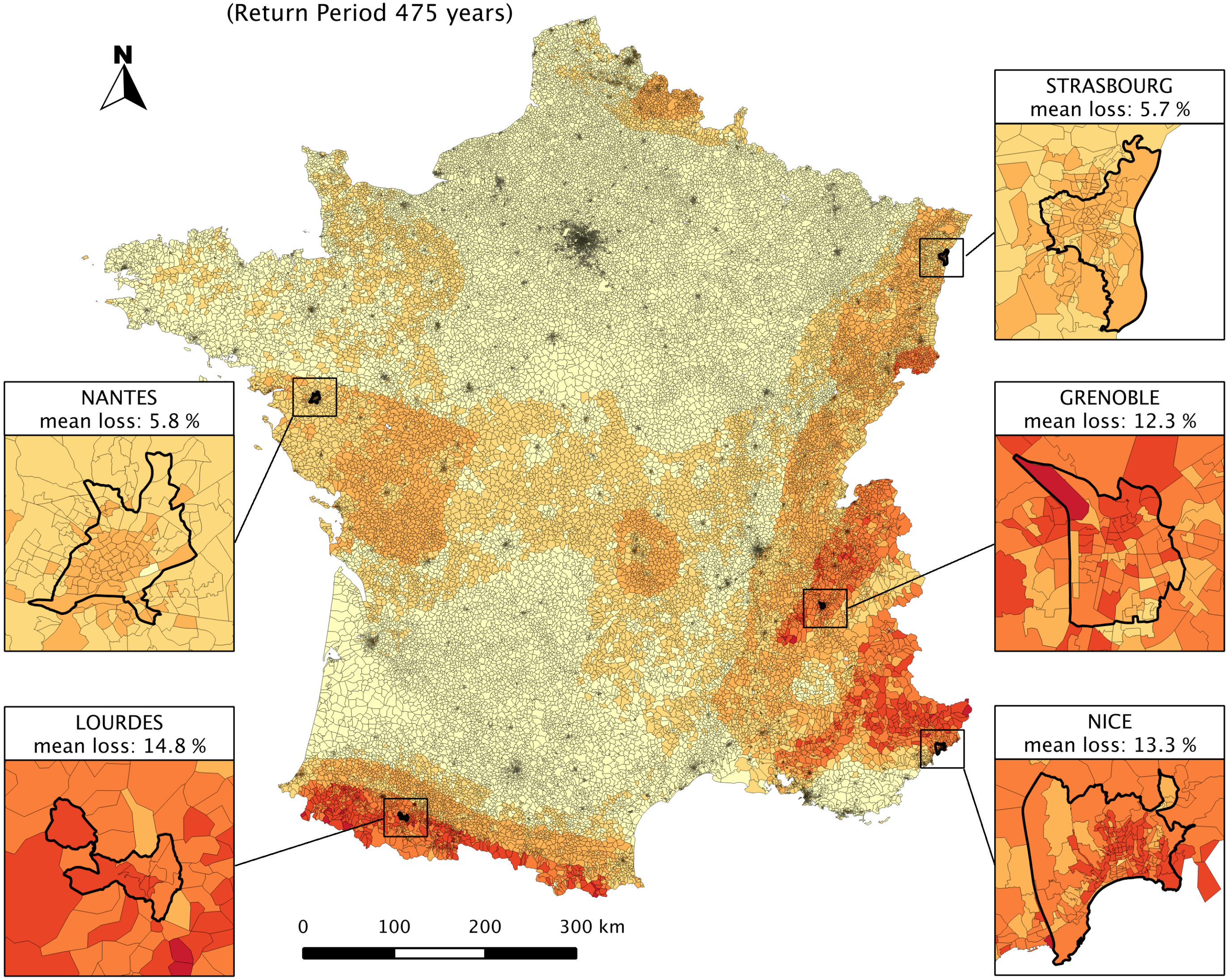
Estimated direct loss for regulatory accelerations [%]

(Return Period 475 years)



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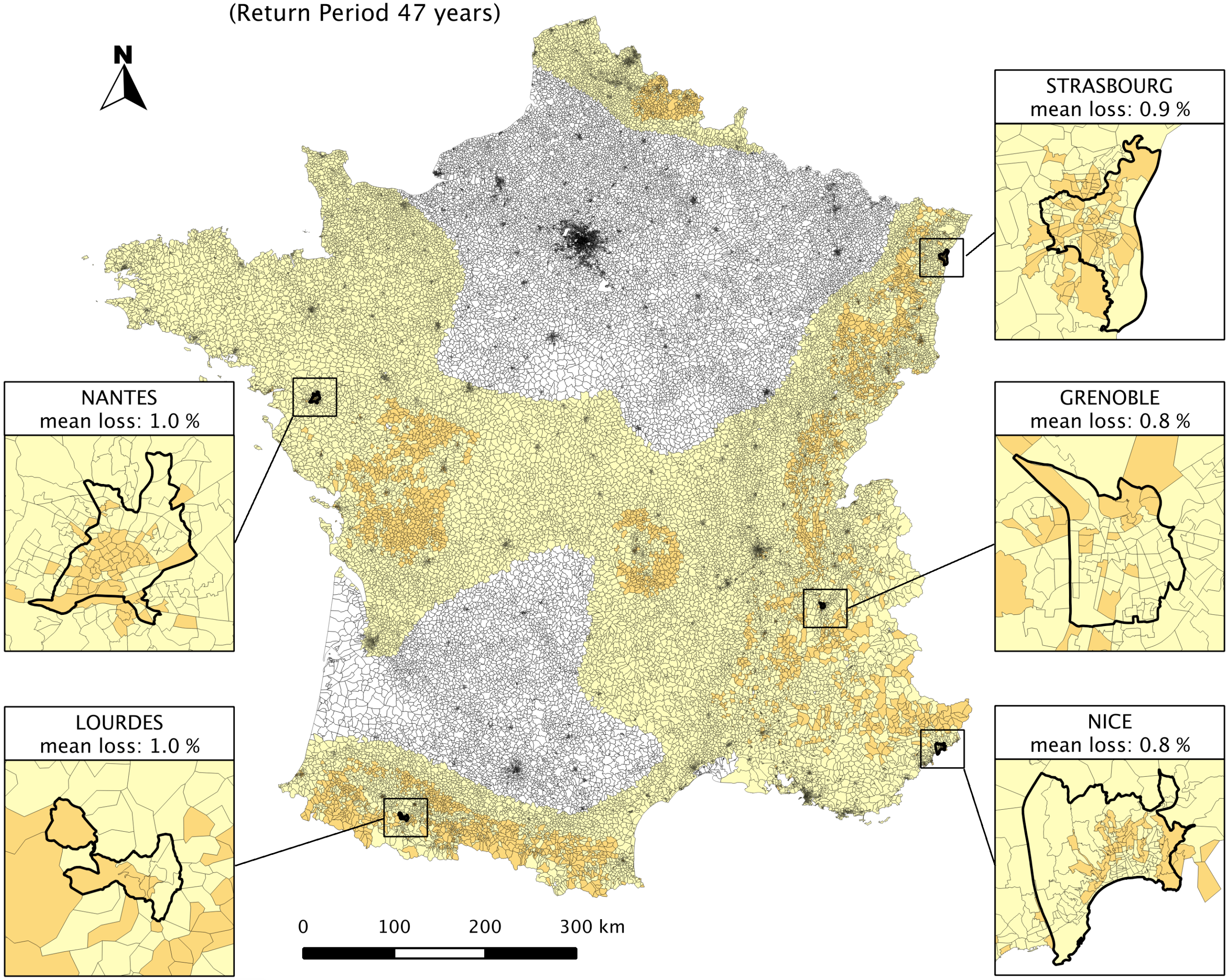
Estimated direct loss for regulatory accelerations [%]

(Return Period 47 years)



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Loss Estimate
(Reference)

$$C^{direct} = \sum_{i=1}^{i=5} P_{Di} * C_{Di}$$

% of buildings with damage Di

Cost of retrofitting

Actual vulnerability class	Final vulnerability class	Cost (%)
A	B	5.0
A	C	14.0
A	D	22.0
B	C	10.0
B	D	20.0
C	D	25.0
C	E	30.0

FEMA 156 (1996)
Rapport GTR/DDT65/0511-855
Smyth et al., (2004)
Kappos & Dimitrakopoulos, (2008)
Bostenaru Dan, (2014)

Retrofitting Schemes

$$I^{total} = \sum P_{X \rightarrow Y} * Q_{X \rightarrow Y}$$

% of buildings class X retrofitted to class Y

New Loss Estimate
(retrofitted)

$$C^{direct} = \sum_{i=1}^{i=5} P_{Di} * C_{Di}$$

New % of buildings with damage Di

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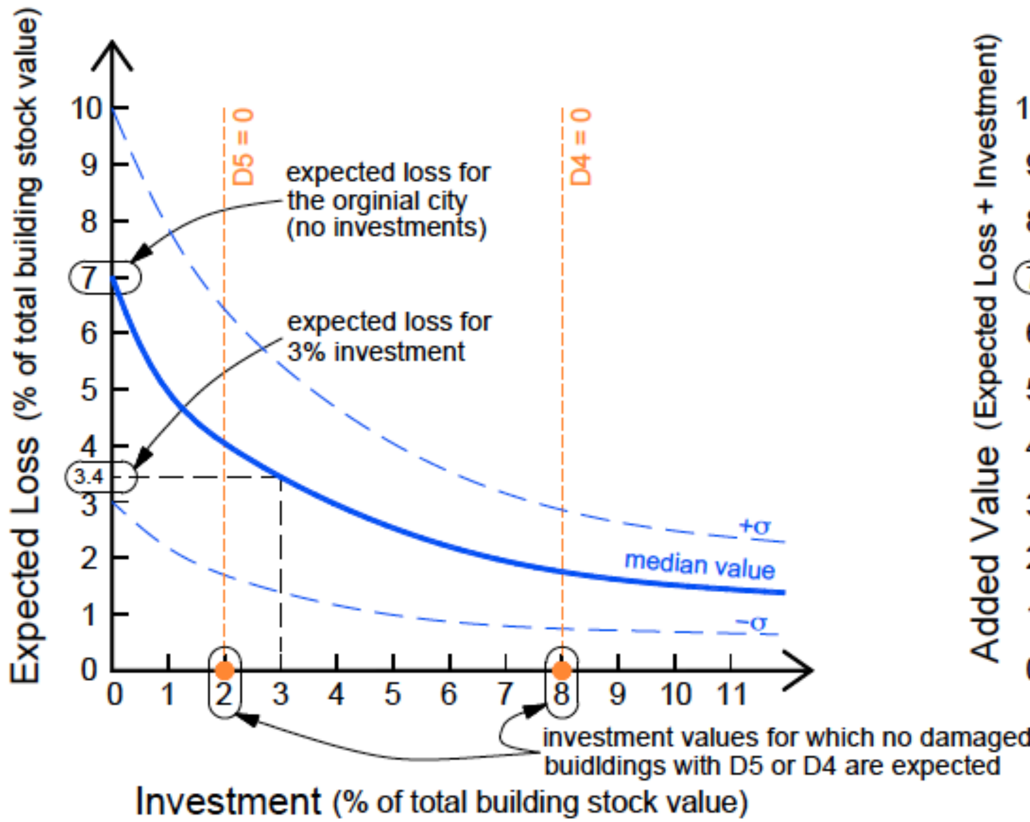
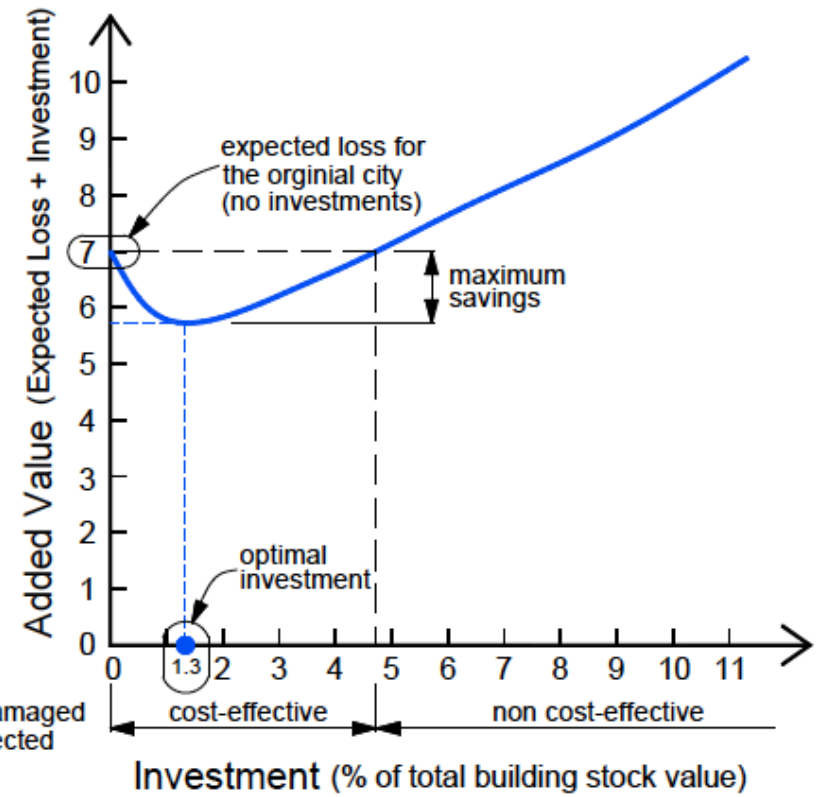
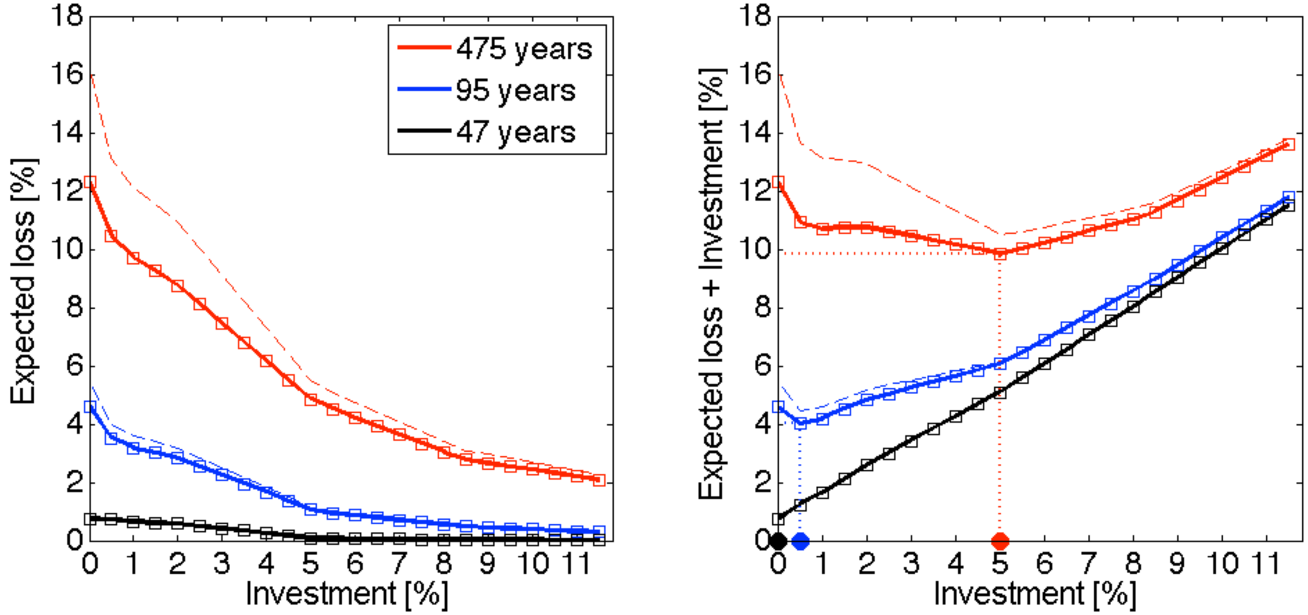
Analyse coût/Bénéfices





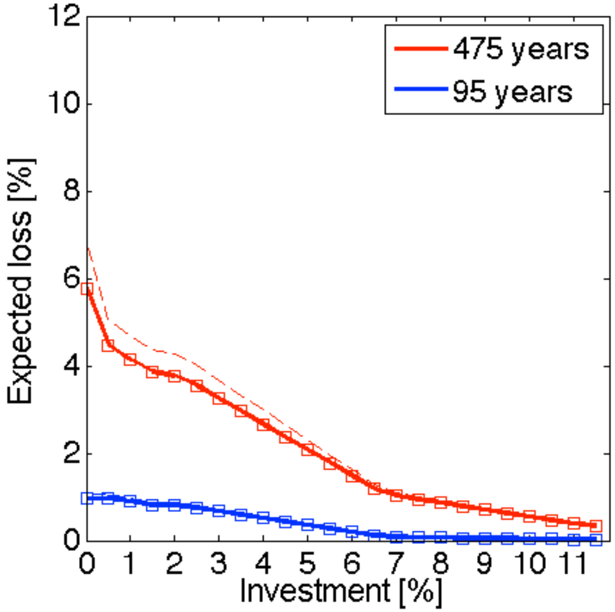
Analyse coût/Bénéfices - GRENOBLE

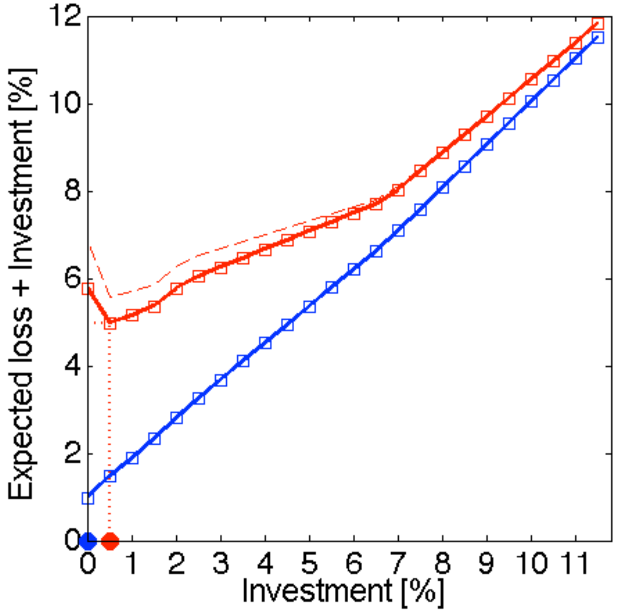


Valeur de l’immobilier résidentiel de Grenoble: €10.2 milliard

Ville	Investis^mt	475 ans		95 ans		47 ans	
		Perte dir	Bénéfice	Perte dir	Bénéfice	Perte dir	Bénéfice
Originale	0	1.3 Mds	0	470 mi	0	77 mi	0
Stratégie Optimale	510 mi	495 mi	295 mi	108	0	10 mi	0

Analyse coût/Bénéfices - NANTES





Valeur de l'immobilier résidentiel de Nantes: €50 milliard

Ville	Investis^mt	475 ans		95 ans		47 ans	
		Perte dir	Bénéfice	Perte dir	Bénéfice	Perte dir	Bénéfice
Originale	0	2.89 Mds	0	492 mi	0	492 mi	0
Stratégie Optimale	250 mi	2.24 Mds	401 mi	490 mi	0	490 mi	0

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pour prévenir les risques

Analyse coût/Bénéfices

NICE	Investis^mt	475 ans		95 ans		47 ans	
		Perte dir	Bénéfice	Perte dir	Bénéfice	Perte dir	Bénéfice
Originale	0	5.52 Mds	0	2.10 Mds	0	343 mi	0
Stratégie Optimale	2.28 Mds	2.12 Mds	1.12 Mds	474 mi	0	45 mi	0

LOURDES	Investis^mt	475 ans		95 ans		47 ans	
		Perte dir	Bénéfice	Perte dir	Bénéfice	Perte dir	Bénéfice
Originale	0	207 mi	0	80 mi	0	14 mi	0
Stratégie Optimale	91 mi	73 mi	42 mi	17 mi	0	2 mi	0

Strasbourg	Investis^mt	475 ans		95 ans		47 ans	
		Perte dir	Bénéfice	Perte dir	Bénéfice	Perte dir	Bénéfice
Originale	0	1.70 Mds	0	283 mi	0	283 mi	0
Stratégie Optimale	150 mi	1.31 Mds	240 mi	282 mi	0	282 mi	0

Conclusions

- Provided tools for earthquake loss assessments in moderate seismicity regions.
  - Data mining techniques allow a simple vulnerability estimation nation-wide.
  - Independent information coming from remote sensed data can increase the accuracy
  - Larger variability coming from Hazard data.
  - Seismic risk is considerable in France due to the evolution of exposure.
- Attempted to implement first diagnosis and decision support tools for risk reduction in France.
  - Retrofitting of structures usually not cost-effective for the shortest time horizons.

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Perspectives

- **On the value of seismic regulation in France**
  - Including a complete PSHA in intensity
  - Low-to-moderate (western) region - What are the impact of the implementation (or not) of the seismic regulation in terms of cost/ benefot analysis?
  - Direct and indirect economic losses - Logic tree based method considering the cost (and benefit) of each decision making.
  - Additional parameters
- **Risk and responsibility**
  - What are the responsibilities of the authorities/owners/insurances with respect to the implementation of the seismic regulation ?

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PHILIPPE GUÉGUEN
ISTERRE/IFSTTAR
philippe.gueguen@univ-grenoble-alpes.fr

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