European Commission

Horizon 2020
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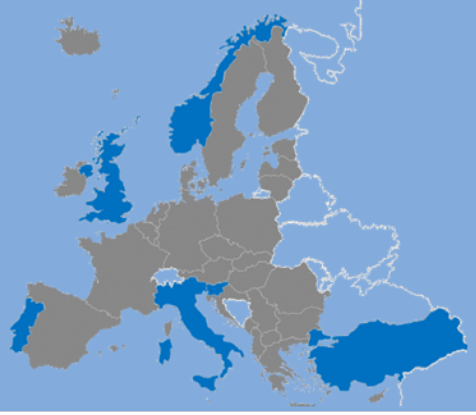
liquefACT



Il progetto LIQUEFACT in Emilia-Romagna

17 Febbraio 2021

MICROZONAZIONE DEL RISCHIO DI LIQUEFAZIONE SISMO-INDOTTA: IL CASO STUDIO DEL COMUNE DI CAVEZZO (MODENA)

UNIVERSITÀ DI PAVIA

UNIPV-Dicar: Prof. Ing. Carlo G. Lai
EUCENTRE: Ing. Francesca Bozzoni
UNIPV-DISTA: Prof. Claudia Meisina

UNIVERSITY OF PAVIA – EUCENTRE

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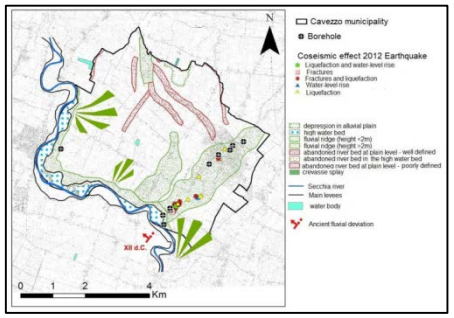
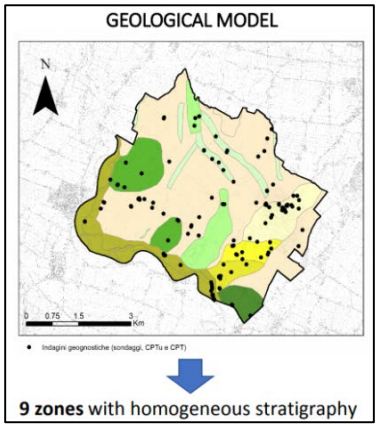
PROCEDURE FOR MICROZONING LIQUEFACTION RISK AT URBAN SCALE: THE CASE-STUDY OF CAVEZZO

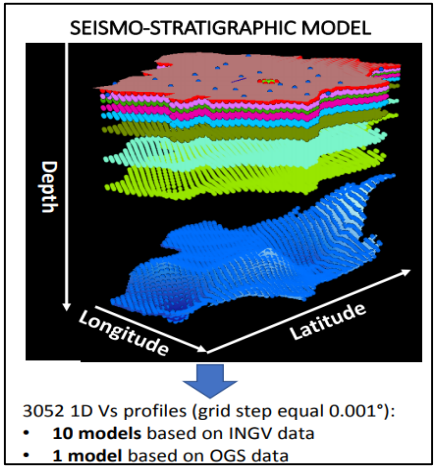
1. Geological, geo-morphological and hydro-geological framework



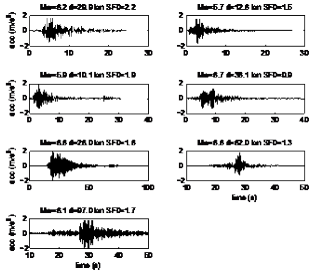
2. Investigation campaigns for geotechnical characterization

3. Definition of subsoil model



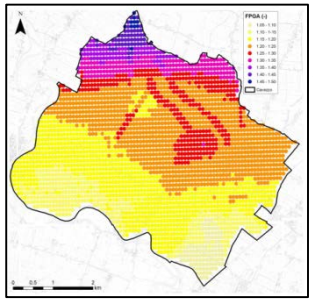


4. Definition of reference seismic Input



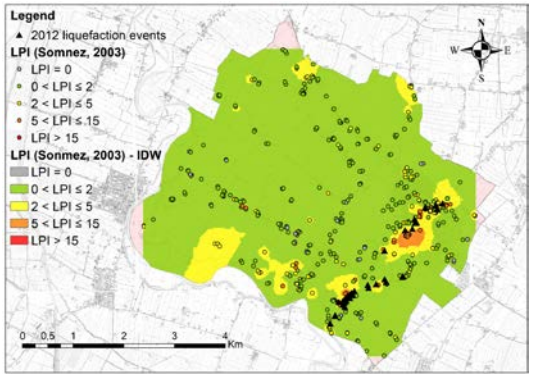
Set of 7 real sismo- and spectrum-compatible accelerograms

5. Ground Response Analyses

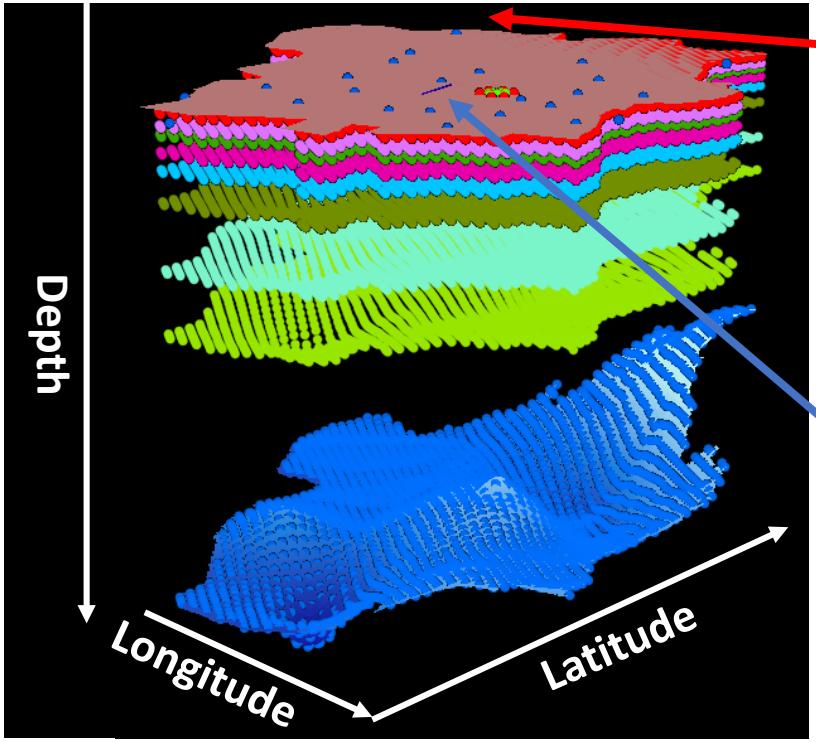


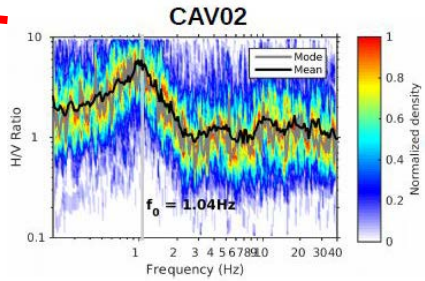
- 475, 975,2475 yrs return periods
- ground response analysis

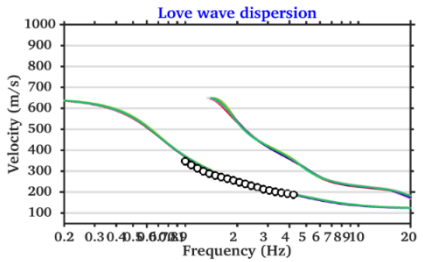
6. Micro-zoning territory of Cavezzo for liquefaction risk

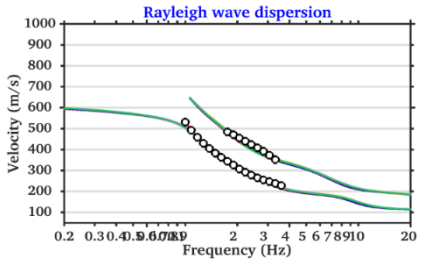


SEISMO-STRATIGRAPHIC PSEUDO 3D MODEL





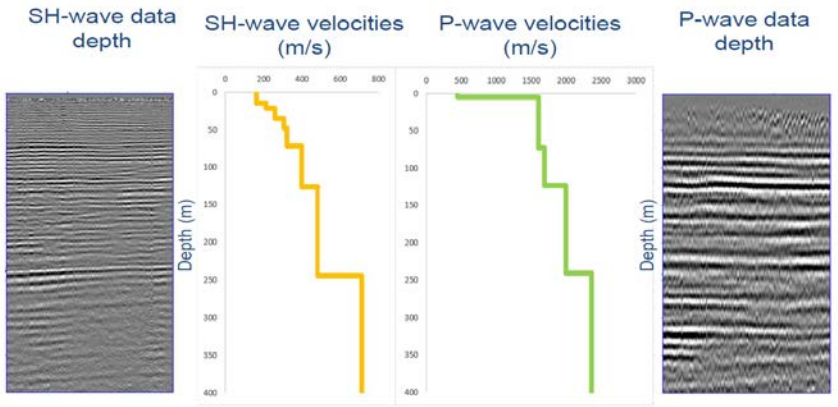




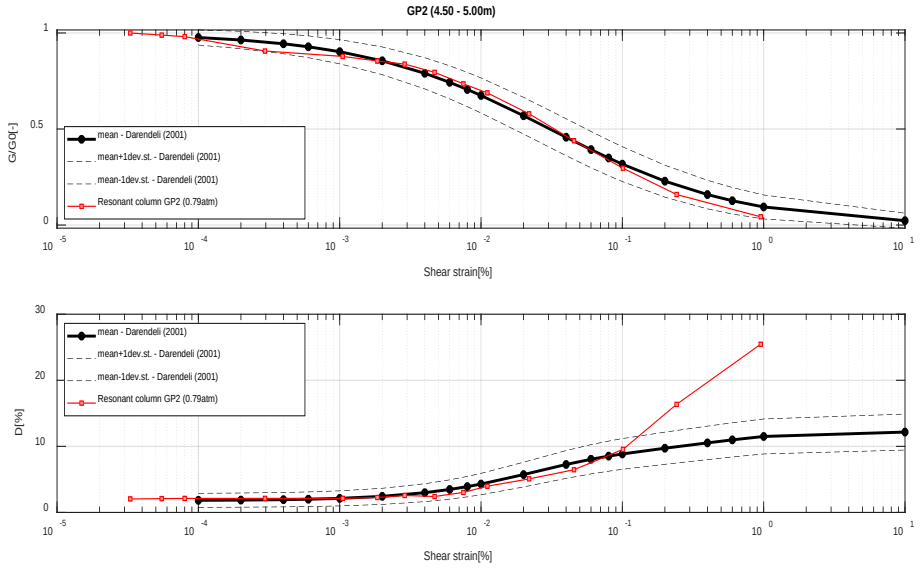
Surface wave ambient vibration method to obtain shallow & deep seismo-stratigraphic 3D model (INGV)

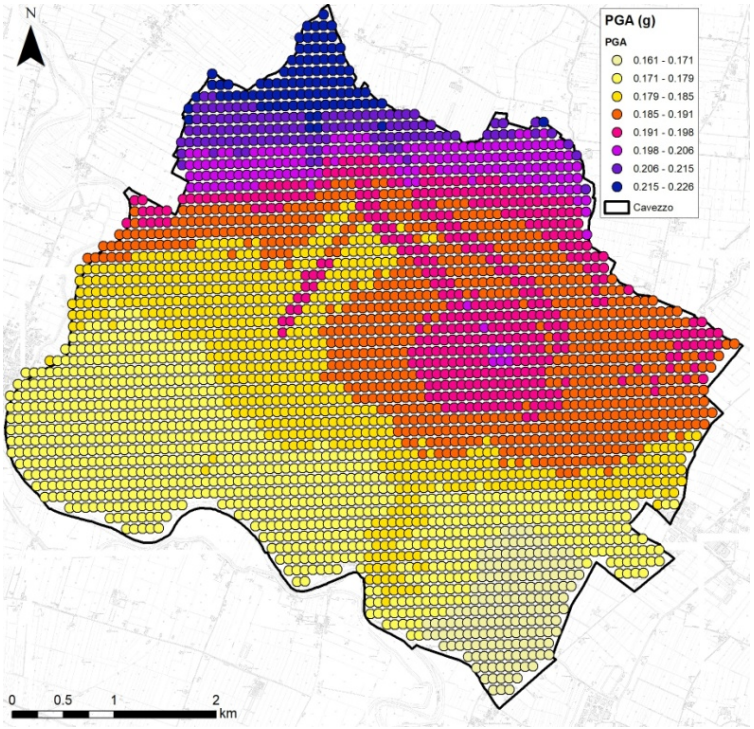
Good match down up to a depth of about 140m where an interface was assumed to represent the seismic bedrock.

High resolution P/S seismic reflection survey (OGS)



PSEUDO-STOCHASTIC 1D GROUND RESPONSE ANALYSES





Calibration of reduction curves using Darendeli (2001) model based on laboratory tests (i.e. RC, DSS test)

$$F^i = \sum_{j=1}^{7} w\_acc_j \sum_{k=1}^{11} w\_mod_k F_{jk}^i$$

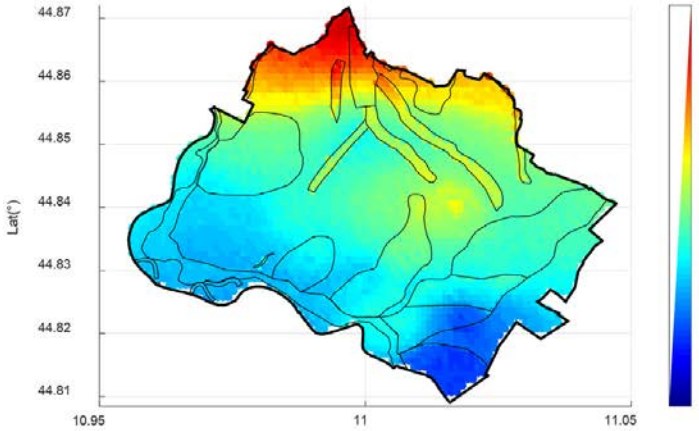
For about 3000 points →

- 5% acceleration response spectra
- 9 amplification factors (F_{PGA}, $FH_{0.1\text{-}0.5s}$, $FH_{0.5\text{-}1s}$, $FH_{0.5\text{-}1.5s}$, $FH_{0.7\text{-}1.1s}$, $FA_{0.1\text{-}0.5s}$, $FA_{0.5\text{-}1s}$, $FA_{0.5\text{-}1.5s}$, $FA_{0.4\text{-}0.8s}$)

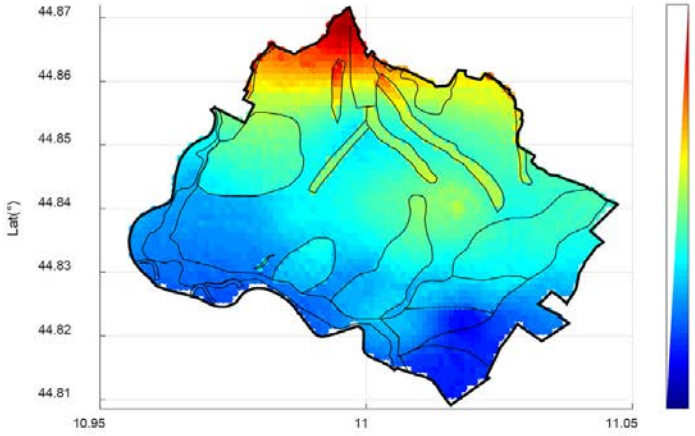
wacc=1/7 → (same weight for 7 accelerograms)
wmod = 0.05 for 10 models INGV; 0.5 for OGS model

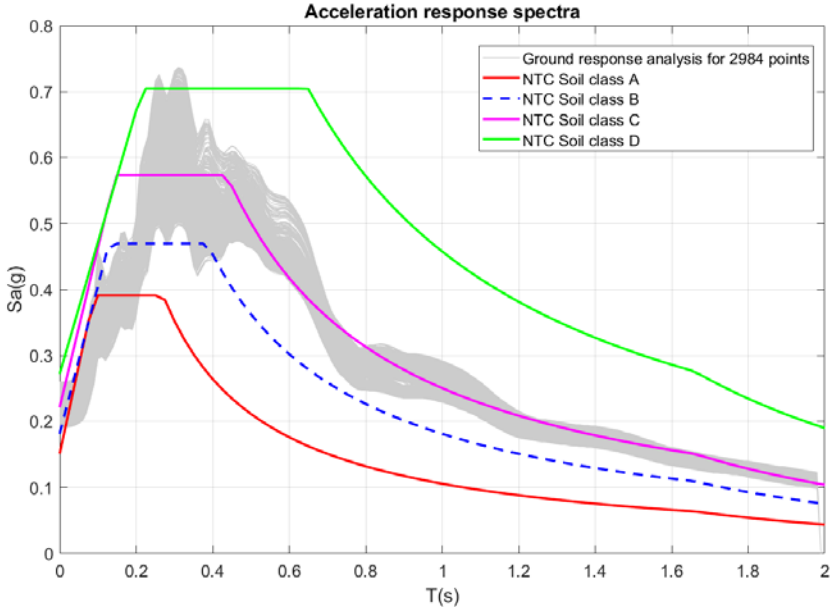
MICROZONING THE TERRITORY FOR EXPECTED GROUND MOTION

Amplification factor peak ground acceleration FPGA



Housner Intensity ratio (0.5s≤T≤1.0s)



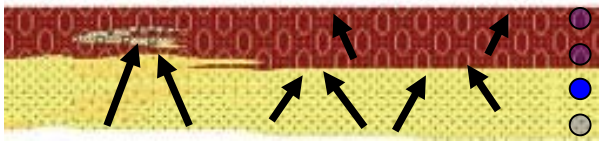


Ground motion amplification factors and acceleration response spectra computed for the municipality of Cavezzo by **1D linear-equivalent** ground response analyses assuming an input motion of 475 years return period.

MICRO-ZONING THE TERRITORY FOR LIQUEFACTION RISK

Computation of FoS and P_L against liquefaction triggering:

CAPACITY of the soil to resist liquefaction triggering
(CRR *Cyclic Resistance Ratio)*



Seismic DEMAND at a point
(CSR *Cyclic Stress Ratio)*

$$F_S = \frac{CRR}{CSR}$$

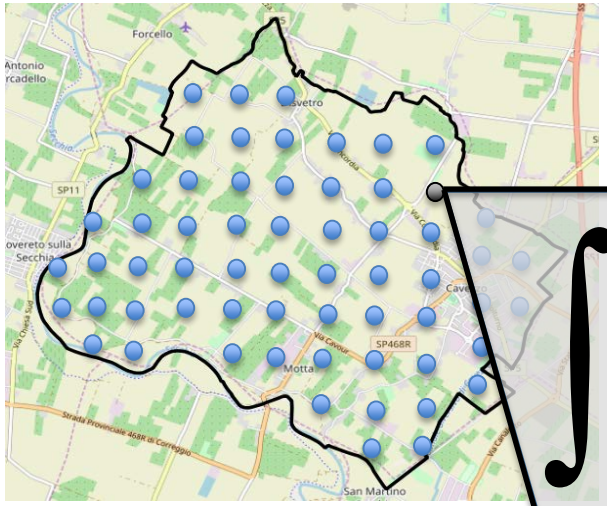
$$P_L = P_L\left(CRR, CSR\right)$$

Laboratory tests or **in-situ tests** (CPT, SPT, V_S)

from GRA

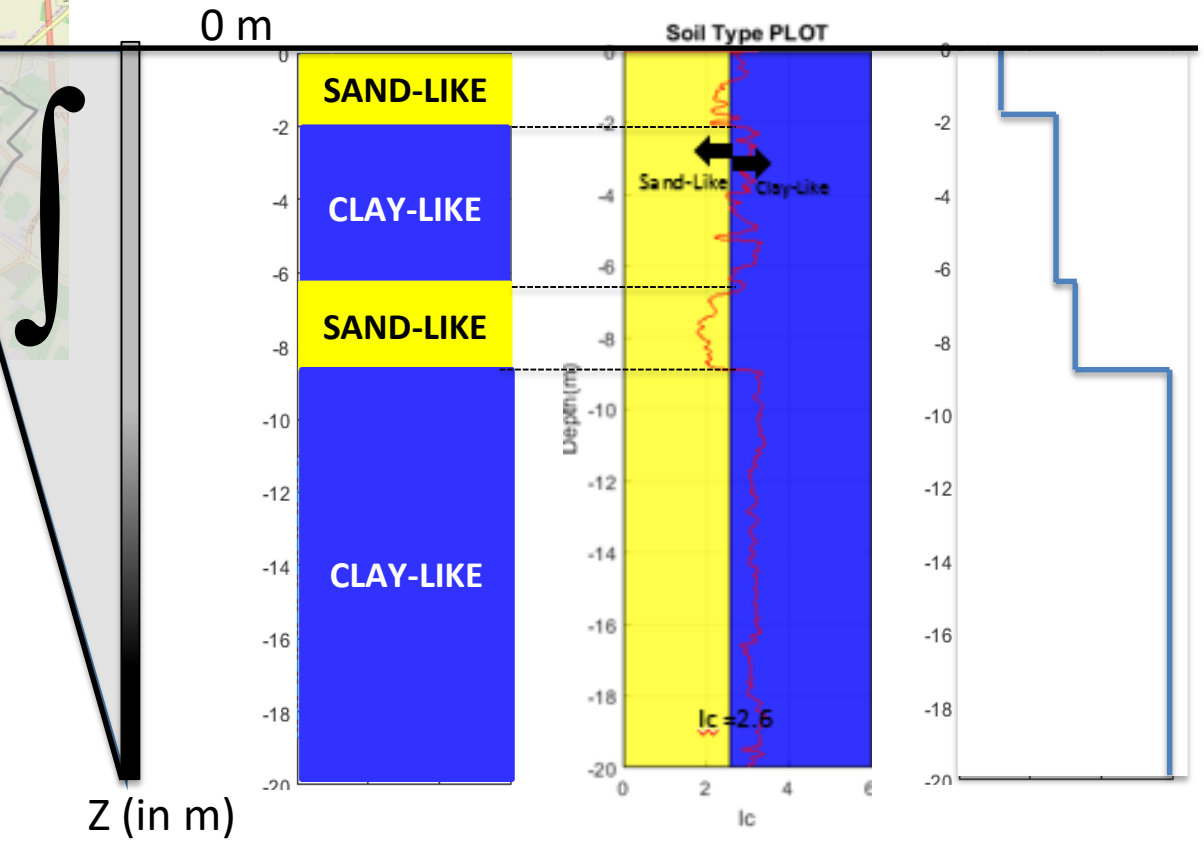
MAPPING THE LIQUEFACTION RISK AT URBAN SCALE

CPT-based methods | **V_S-based method**



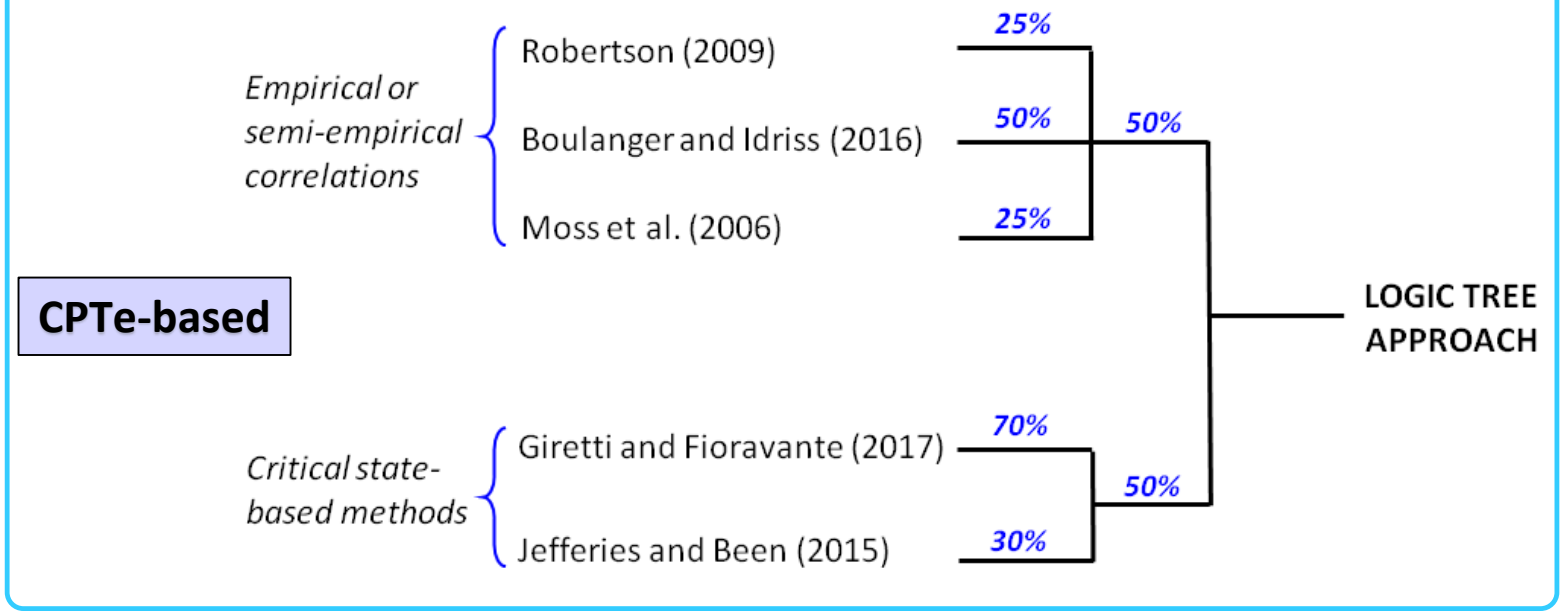
Point-wise assessment at different depths combined into a **single index** to yield **LPI** & **LSI**.

Empirical approaches for assessment of liquefaction-induced settlements and lateral displacements, also in terms of **scalar indices** e.g. **LSN** & **LDI**.



LIQUEFACTION VULNERABILITY BY IN-SITU TESTS METHODS TAKING INTO ACCOUNT THE EPISTEMIC UNCERTAINTY

CRR from ~ 450 CPT/CPTU



CPTm-based Boulanger and Idriss (2016) corrected by Facciorusso et al. (2017)

V_S-based Kayen et al. (2013; 2014)

MONTE CARLO SIMULATIONS

1) the input variables are modeled with their uncertainty (i.e. probability distribution)
2) n simulation computed
3) finally the results from each simulation are processed and the mean results are computed

1)

Water table depth

- normal distribution
- COV 20%

Threshold value Ic

- Discrete distribution
- [2.4 2.5 2.6 2.7]

CSR from GRA

- Discrete distribution
- 7 real accelerograms

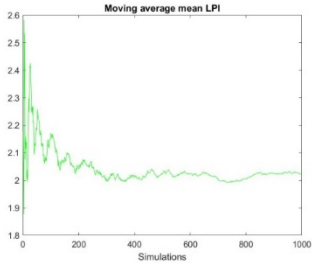
2)

n simulations

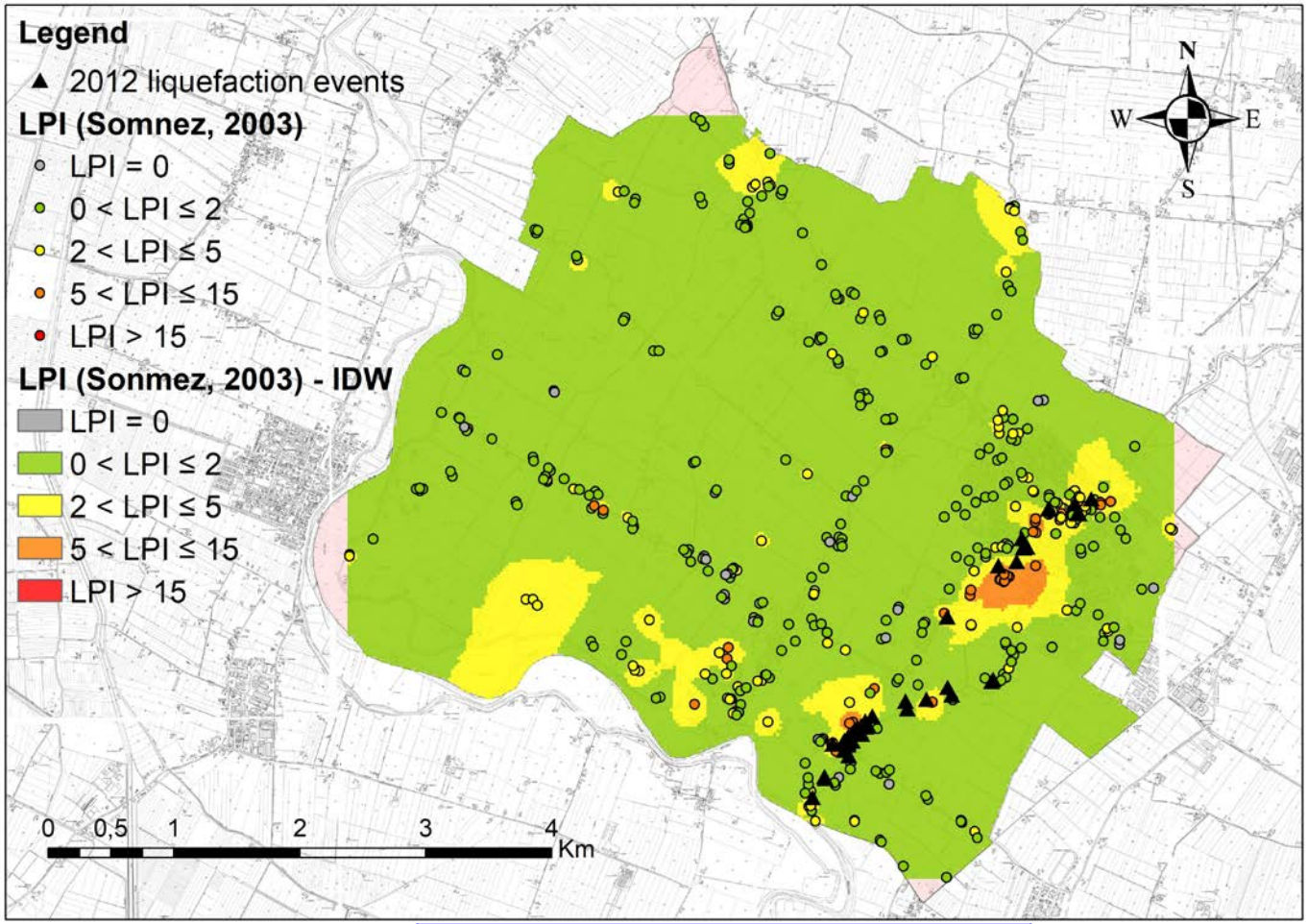
Logic tree -> engine of novel algorithm to carry out Monte Carlo simulations for probabilistic assessment of liquefaction risk in a territory of relatively large size

3)

Final **mean** result (e.g. LPI mean value)



MAP OF LIQUEFACTION POTENTIAL INDEX (LPI)



from Monte Carlo simulations

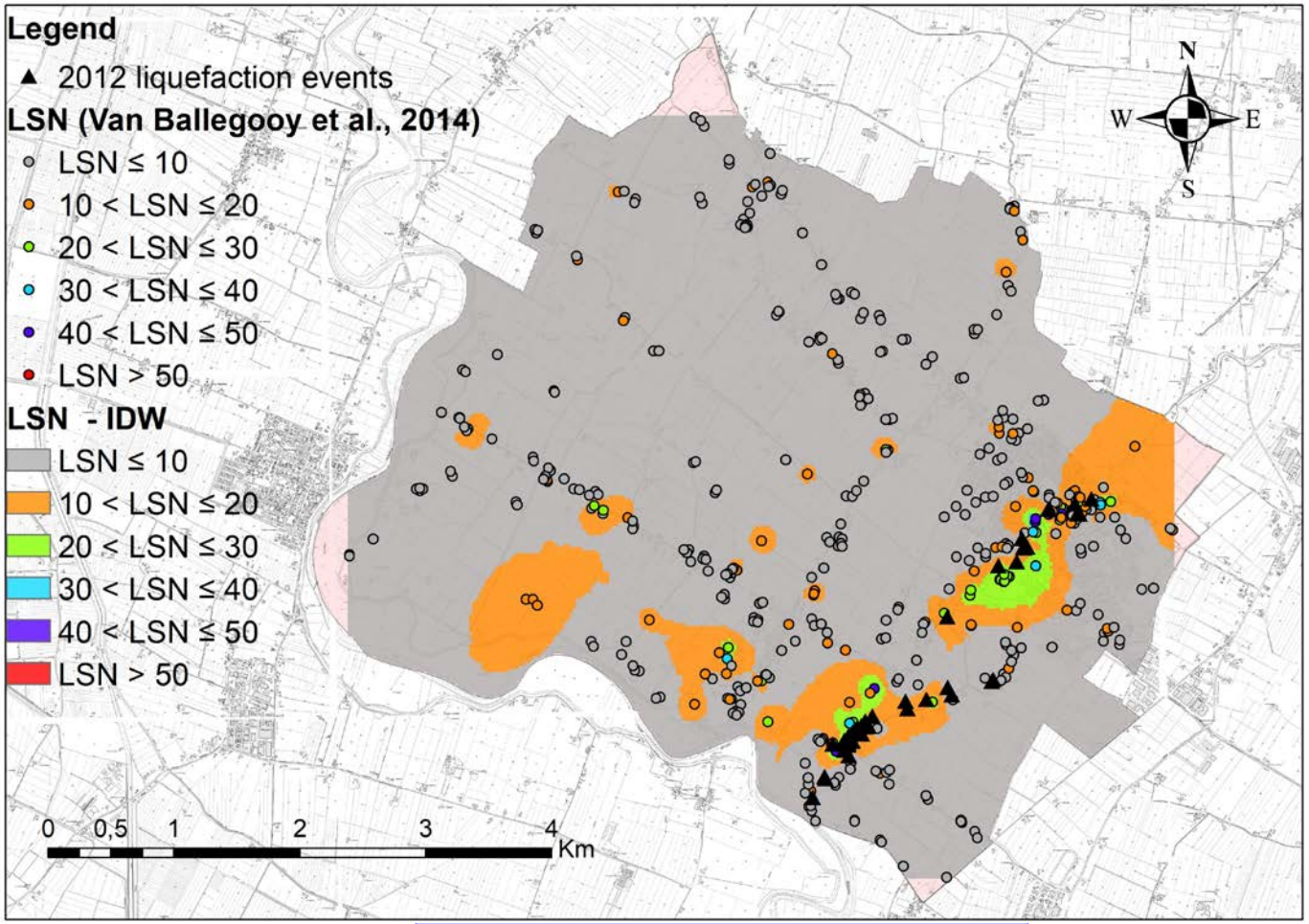
CPT-based methods

Spatial interpolation using different algorithms (e.g. IDW, kriging)

Return Period: **475 years**

Black dots: **2012 liquefaction** manifestations

MAP OF LIQUEFACTION SEVERITY NUMBER (LSN)



from Monte Carlo simulations

CPT-based methods

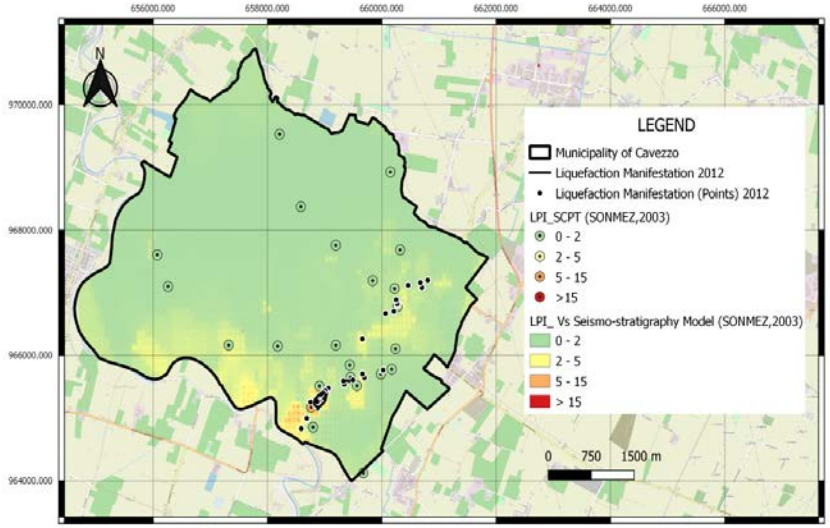
Spatial interpolation using different algorithms (e.g. IDW, kriging)

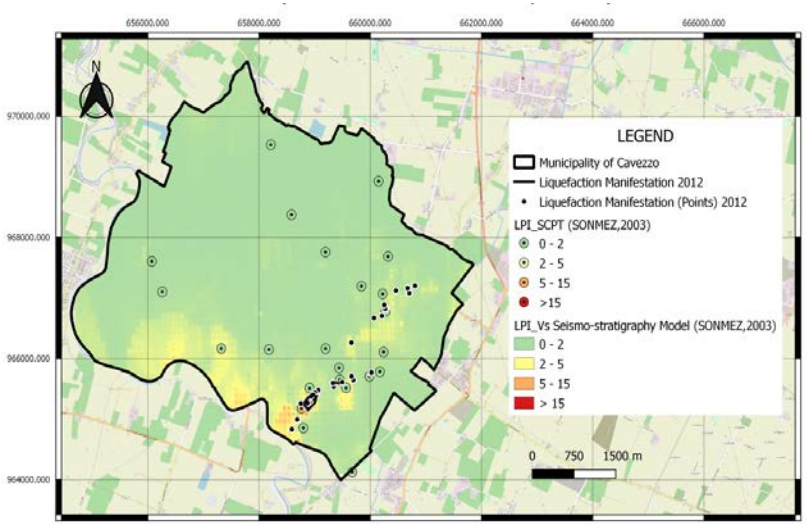
Return Period: **475 years**

Black dots: **2012 liquefaction** manifestations

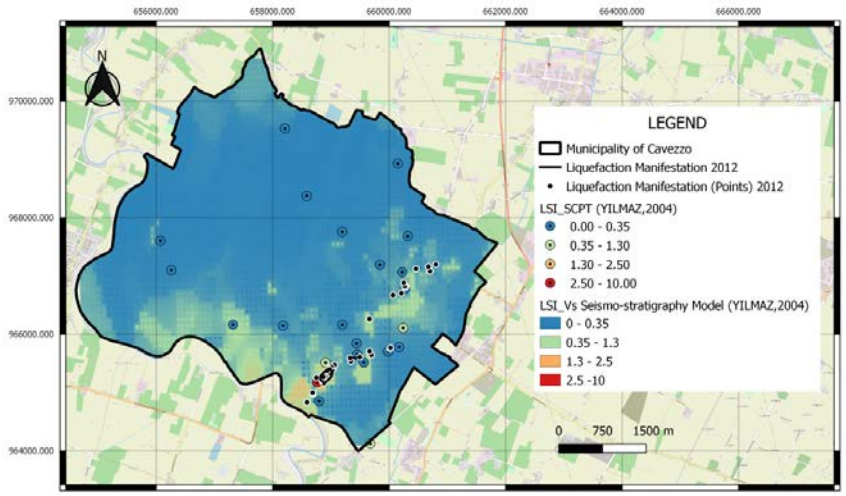
MAP OF V_S-BASED ASSESSMENT OF LIQUEFACTION RISK

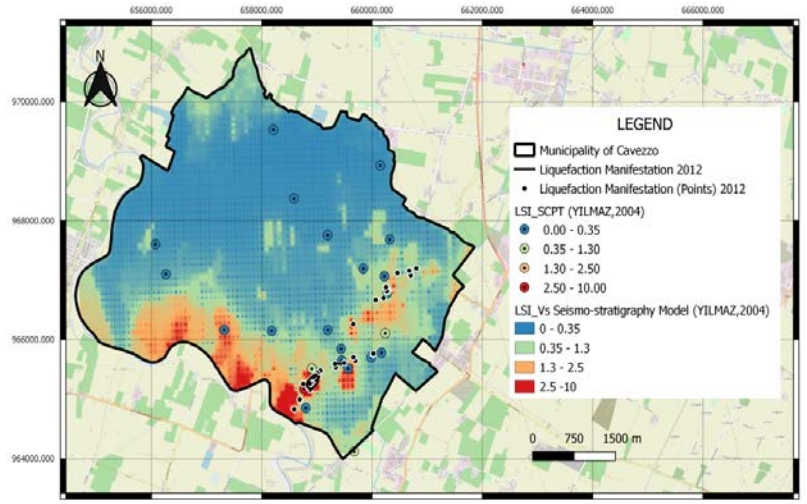
LPI





LSI



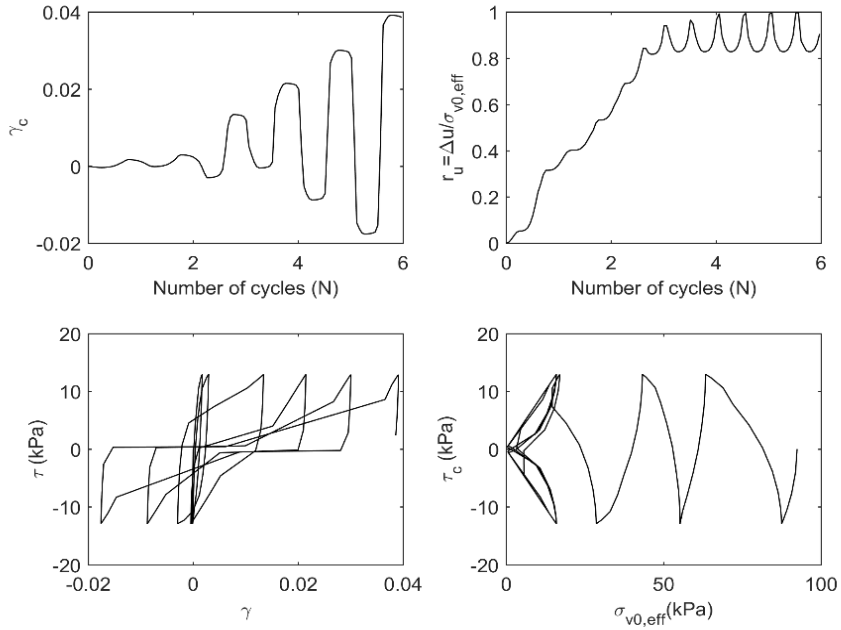


Vs-based method

from Monte Carlo simulations

FULLY COUPLED NON-LINEAR EFFECTIVE STRESS ANALYSES AT A FEW SITES IN CAVEZZO

Site of school in Uccivello di Cavezzo



Calibration of advanced numerical model **PDMY02** implemented in **OpenSees**. Based on nested multi-yield surfaces to model the soil nonlinearity, the idea behind of which was originally proposed by Prevost (1985). Then, it is further developed by Yang et al. (2003).

PEER-REVIEWED SCIENTIFIC PUBLICATIONS

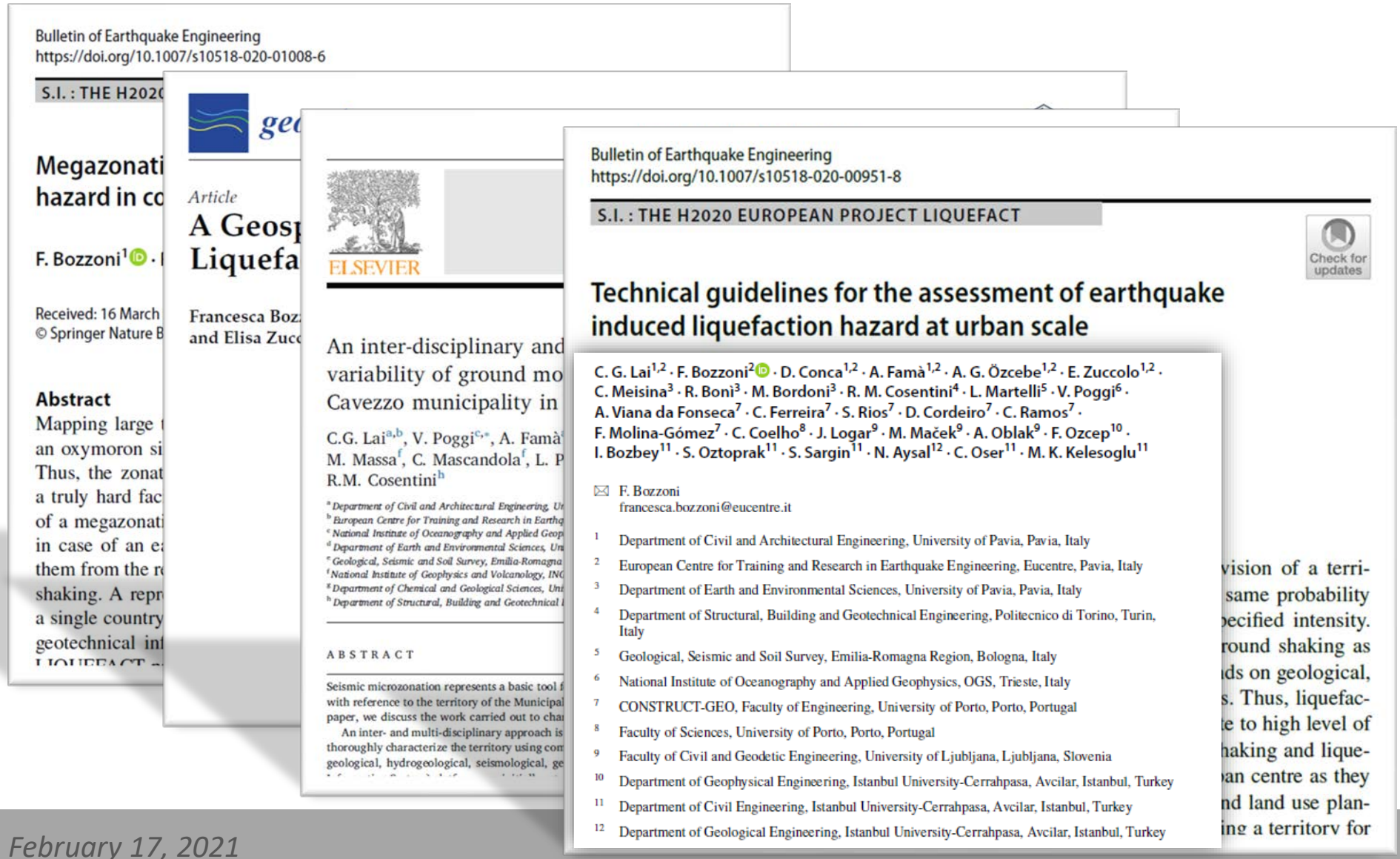
1) Bozzoni, F., Bonì, R., Conca, D., Meisina, C., Lai, C.G., Zuccolo, E. (2021). "A geospatial approach for mapping the earthquake-induced liquefaction risk at European scale", Geosciences 2021, 11, 32. https://doi.org/10.3390/geosciences11010032.

2) Bozzoni, F., Bonì, R., Conca, D., Lai, C.G., Zuccolo, E., Meisina, C. (2020). "Megazonation of earthquake-induced soil liquefaction hazard in continental Europe", Bulletin of Earthquake Engineering. https://doi.org/10.1007/s10518-020-01008-6.

3) Lai, C.G., Bozzoni, F., Conca, D., Famà, A., Özcebe, A.G., Zuccolo, E., Meisina, C., Bonì, R., Bordoni, M., R.M. Cosentini, L. Martelli, V. Poggi, A. Viana da Fonseca, C. Ferreira, S. Rios, D. Cordeiro, C. Ramos, F. Molina-Gómez, C. Coelho, J. Logar, M. Maček, A. Oblak, F. Ozcep, I. Bozbey, S. Oztoprak, S. Sargin, N. Aysal, C. Oser, Kelesoglu M.K. (2020). "Technical guidelines for the assessment of earthquake induced liquefaction hazard at urban scale", Bulletin of Earthquake Engineering. https://doi.org/10.1007/s10518-020-00951-8.

4) Lai, C.G., Poggi, V., Famà, A., Zuccolo, E., Bozzoni, F., Meisina, C., Bonì, R., Martelli, L., Massa, M., Mascandola, C., Petronio, L., Affatato, A., Baradello, L., Castaldini, D., Cosentini, R.M. (2020) "An inter-disciplinary and multi-scale approach to assess the spatial variability of ground motion for seismic microzonation: the case study of Cavezzo municipality in Northern Italy", Engineering Geology, 274, 5. https://doi.org/10.1016/j.enggeo.2020.105722.

PEER-REVIEWED SCIENTIFIC PUBLICATIONS



Bulletin of Earthquake Engineering
https://doi.org/10.1007/s10518-020-01008-6

S.I. : THE H2020

Megazonati
hazard in co

F. Bozzoni[1] · I

Received: 16 March
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Abstract

Mapping large
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Article

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Francesca Boz
and Elisa Zucc

ELSEVIER

An inter-disciplinary and
variability of ground mo
Cavezzo municipality in

C.G. Lai[a,b], V. Poggi[c,*], A. Famà
M. Massa[f], C. Mascandola[f], L. P
R.M. Cosentini[h]

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[b] European Centre for Training and Research in Earthq
[c] National Institute of Oceanography and Applied Geop
[d] Department of Earth and Environmental Sciences, Un
[e] Geological, Seismic and Soil Survey, Emilia-Romagna
[f] National Institute of Geophysics and Volcanology, ING
[g] Department of Chemical and Geological Sciences, Uni
[h] Department of Structural, Building and Geotechnical

ABSTRACT

Seismic microzonation represents a basic tool f
with reference to the territory of the Municipal
paper, we discuss the work carried out to cha
An inter- and multi-disciplinary approach is
thoroughly characterize the territory using com
geological, hydrogeological, seismological, ge

Bulletin of Earthquake Engineering
https://doi.org/10.1007/s10518-020-00951-8

S.I. : THE H2020 EUROPEAN PROJECT LIQUEFACT

Check for updates

Technical guidelines for the assessment of earthquake induced liquefaction hazard at urban scale

C. G. Lai[1,2] · F. Bozzoni[2] · D. Conca[1,2] · A. Famà[1,2] · A. G. Özcebe[1,2] · E. Zuccolo[1,2] · C. Meisina[3] · R. Boni[3] · M. Bordoni[3] · R. M. Cosentini[4] · L. Martelli[5] · V. Poggi[6] · A. Viana da Fonseca[7] · C. Ferreira[7] · S. Rios[7] · D. Cordeiro[7] · C. Ramos[7] · F. Molina-Gómez[7] · C. Coelho[8] · J. Logar[9] · M. Maček[9] · A. Oblak[9] · F. Ozcep[10] · I. Bozbey[11] · S. Oztoprak[11] · S. Sargin[11] · N. Aysal[12] · C. Oser[11] · M. K. Kelesoglu[11]

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11 Department of Civil Engineering, Istanbul University-Cerrahpasa, Avcilar, Istanbul, Turkey
12 Department of Geological Engineering, Istanbul University-Cerrahpasa, Avcilar, Istanbul, Turkey

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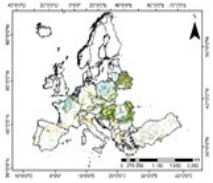
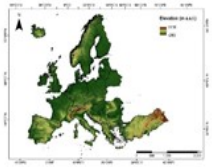
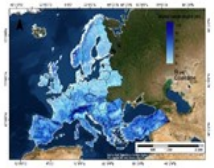
RECENT PRODUCTS (PUBLICATIONS UNDER REVIEW)

LIQUEFACTION SUSCEPTIBILITY ASSESSMENT IN EUROPE

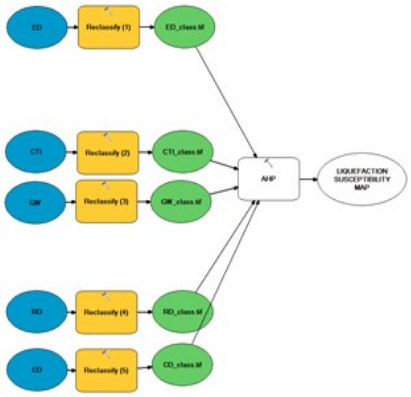
(1) DATA PRE-PROCESSING

Data source	Input data
 European Soil Database (ESDB)	Environment of deposition (ED)
 Shuttle Radar Topography Mission (SRTM)	Compound Topographic Index (CTI)
 • Global patterns of groundwater table depth • Hydrography of Europe • Europe coastline	Water table depth (GW) Distance to river (RD) Distance to coast (CD)

2) LIQUEFACTION SUSCEPTIBILITY MAPPING AT THE EUROPEAN SCALE (LSE)

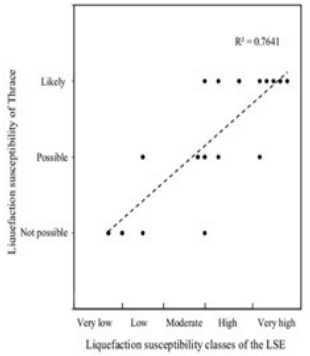
European Macrounits for earthquake-induced soils liquefaction

Analitycal hierarchy approach



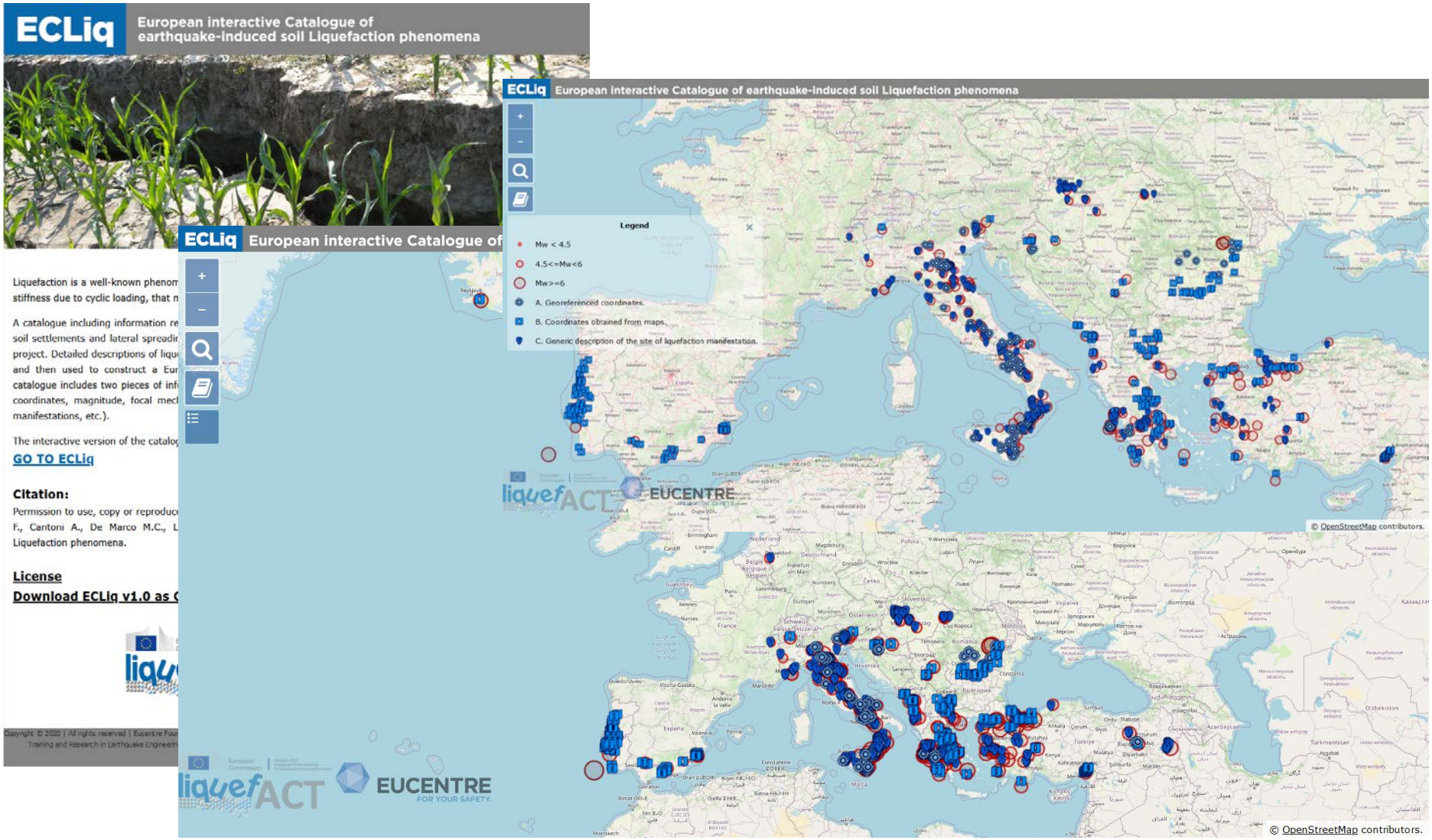
(3) VALIDATION

Cross-comparison with:
- inventory
- National and regional liquefaction susceptibility map



RECENT PRODUCTS (PUBLICATIONS UNDER REVIEW)

ECLIQ - EUROPEAN INTERACTIVE CATALOGUE OF EARTHQUAKE-INDUCED SOIL LIQUEFACTION PHENOMENA



GRAZIE PER L'ATTENZIONE