**REGIONE TOSCANA**

**Direzione Ambiente ed Energia**
**Settore Sismica Regionale - Prevenzione Sismica**

# CPT DATABASE OF THE TUSCANY REGION AND LIQUEFACTION RISK

Workshop on CPT test

Dr. Geol. Massimo Baglione – Settore Sismica

Pisa, 14 June 2019

# Summary

- **Liquefaction Risk;**

- **Liquefaction hazard evaluation** for a 3^d Level Microzonation study in a high seismicity area of Central Italy: Case histories

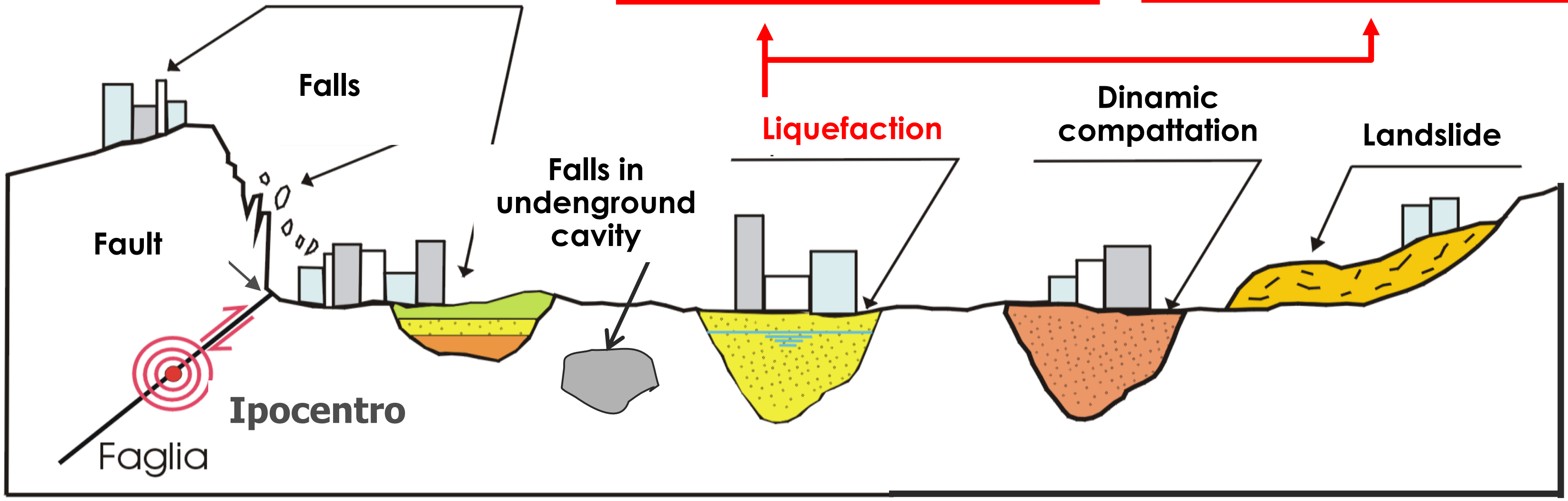
- **CPT Database** of the Tuscany Region

# POSSIBLE SITE EFFECTS

*Seismic Amplification*

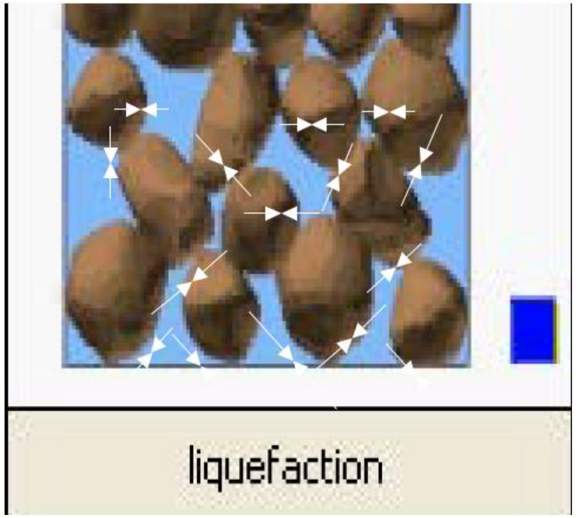
Site effects

*Soil Failure*



# LIQUEFACTION RISK

**Soil liquefaction** occurs when a saturated or partially saturated soil substantially loses strength and stiffness in response to an applied stress such as shaking during an earthquake or other sudden change in stress condition. As a consequence of pore pressure increase the soil becomes liquid.




Different types of liquefaction:
- Ciclyc liquefaction;
- Ciclyc mobility;
- Fluidification

$$\tau_f = \sigma' \cdot \tan\phi' = (\sigma - u) \cdot \tan\phi'$$

(Mohr-Coulomb failure criterion)

# Examples of liquefaction phenomena

Southern Calabria (Italy) February 5, 1783 M7.3 earthquake

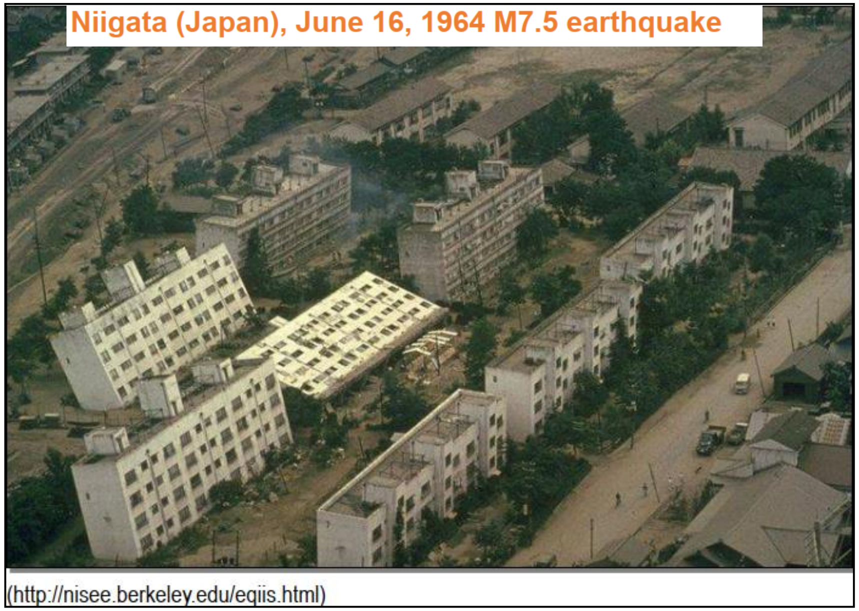
(Sarconi, 1784 cited by Galli, 2000)

Friuli (Italy), May 6, 1976 M6.5 earthquake

(by courtesy of eng. Massimo Blasone – picture shot from geol. Livio Siro)

Sand boils

# Examples of liquefaction phenomena





Cedimenti post-sismici

# Examples of liquefaction phenomena

## Christchurch (New Zealand), February 22, 2011 M6.2 earthquake

# Examples of liquefaction phenomena

Emilia (Northern Italy), May 20, 2012 M6.1 earthquake


Emilia (Northern Italy), May 20, 2012 M6.1 earthquake


Emilia (Northern Italy), May 20, 2012 M6.1 earthquake


Sand boils

# Examples of liquefaction phenomena

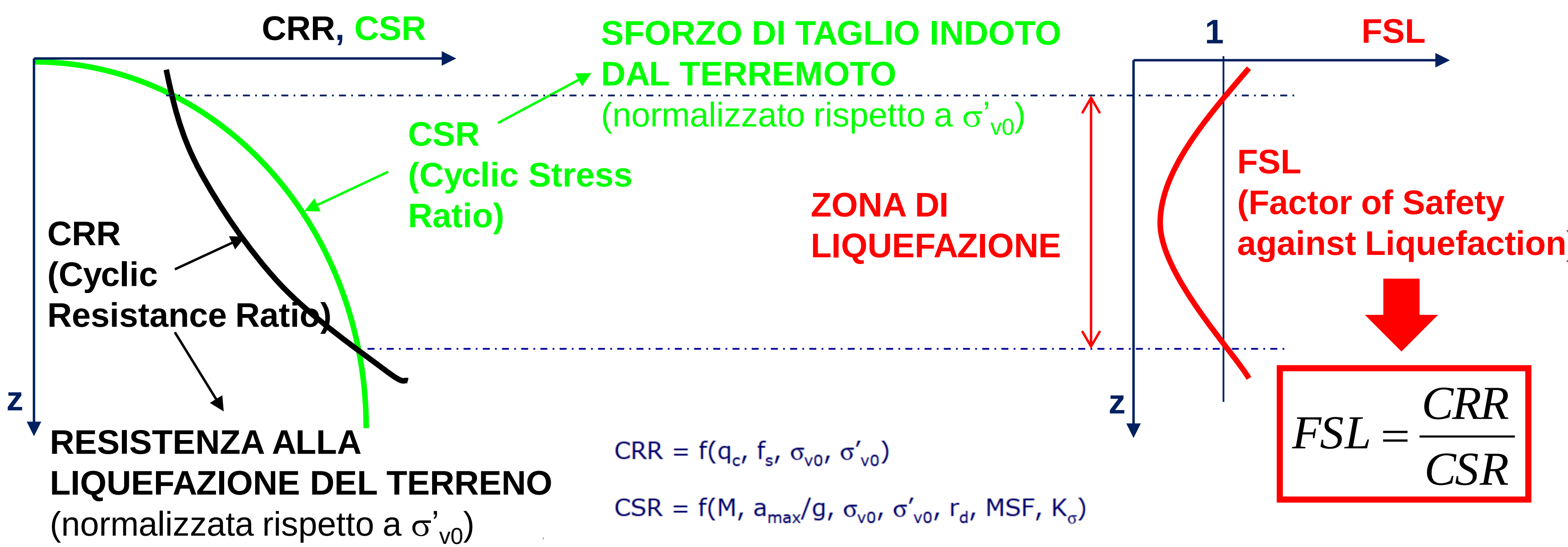
Kaikoura (New Zealand), November 14, 2016 M7.8 earthquake


Aquila, 6 Aprile 2009 – M 5.8



## *Semplified methods for liquefaction estimation*

Several simplified methods have been based on CPT results following both deterministic and probabilistic approaches (e.g. Robertson and Wride 1998; Juang et al. 2002, 2006; Cetin et al. 2004; Moss 2003; Moss et al. 2006; Idriss and Boulanger 2008; Robertson 2009, Boulanger and Idriss 2014).




$CRR = f(q_c, f_s, \sigma_{v0}, \sigma'_{v0})$

$CSR = f(M, a_{max}/g, \sigma_{v0}, \sigma'_{v0}, r_d, MSF, K_\sigma)$

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

Liquefaction risk, at a given site may be evaluated by Indexes like LPI (Liquefaction Potential Index)

$$LPI = \int_0^{z_{crit}} F(z) \cdot w(z)\, dz$$

## Semplified methods for liquefaction estimation

$z_{crit}$: critical depth usually equal to 20m or even less (i.e. 15 or 10m). Liquefiable layers at depths greater than zcrit do not produce effects at ground level

$$LPI = \int_0^{z_{crit}} F(z) \cdot w(z)\, dz$$

w(z): this function gives different weight to the occurrence of liquefaction at different depths

$$w(z) = \frac{200}{z_{crit}} \cdot \left(1 - \frac{z}{z_{crit}}\right)$$

F(z): depends on the Liquefaction Safety Factor (FSL) with values in between 0 and 1

$$F(z) = \begin{cases} 0 & per\ FSL \geq 1.2 \\ 2 \cdot 10^6 \cdot \exp(-18.427 \cdot FSL(z)) & per\ 0.95 < FSL < 1.2 \\ 1 - FSL(z) & per\ FSL \leq 0.95 \end{cases}$$

*Liquefaction Risk (Sonmez, 2003)*

| LPI | rischio di liquefazione |
|---|---|
| ≅ 0 | nullo |
| 0 < LPI ≤ 2 | basso |
| 2 < LPI ≤ 5 | moderato |
| 5 < LPI ≤ 15 | alto |
| LPI > 15 | molto alto |

Liquefaction risk evaluation based on LPI (zcrit = 20 m)

Il calcolo di FSL è escluso per gli strati giudicati non liquefacibili da un punto di vista fisico ($z>z_{cr}$, $z<z_w$), litologico (ad es. $I_c>2.6$) o meccanico (ad es. $(qc_{1n})_{cs}>160$).

# **Liquefaction hazard evaluation**
# for a 3^d Level Microzonation study in a high seismicity area of Central Italy: Case histories

# LIQUEFACTION HAZARD EVALUATION

Microzonation studies for liquefaction hazard generally cover **wide areas** and require many in situ tests performed at great density in order to gain more accurate estimate of the soil liquefaction potential.

**CPTs are frequently preferred** over other in situ tests used in evaluating soil liquefaction potential such as Standard Penetration Tests or in-hole/surface geophysical tests for shear wave velocity measurement.

CPT-based approaches for liquefaction estimation are based on empirical relationships developed from worldwide seismic liquefaction case histories. The most recently compiled and widely used CPT-based methods refer to data obtained from electrical cone penetrometers or piezocones. However, it cannot be excluded that some early relationships for liquefaction evaluation are based on data collected using a mechanical cone Electrical CPT-based methods applied to mechanical CPT data without any form of correction lead to erroneous estimates of liquefaction resistance and significantly non-conservative results. In fact, the sleeve friction, fs, is affected by the greatest error when a mechanical penetrometer is used. Sleeve friction has the greatest influence on the fine content and plasticity index assessment and, consequently, on soil classification and liquefaction susceptibility estimation.

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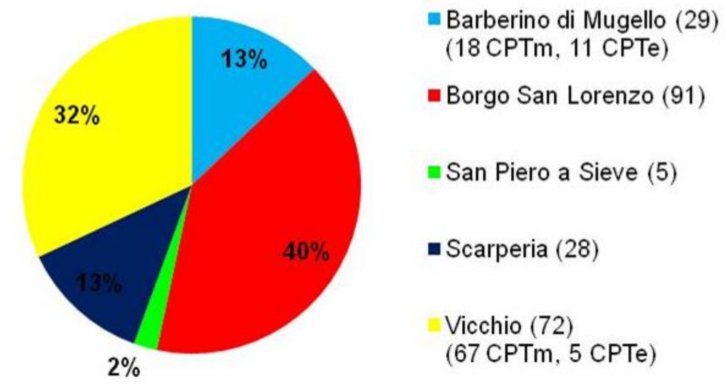
# CASE HISTORIES n.1

**ANALISI E STUDI FINALIZZATI ALLA VERIFICA DELLA SUSCETTIBILITÀ A LIQUEFAZIONE DEI TERRENI NELL'AREA DEL MUGELLO**

Convenzione stipulata tra Regione Toscana - Dir. Ambiente ed Energia - Settore Sismico Regionale Prevenzione Sismica e Università degli Studi di Firenze - Dipartimento di Ingegneria Civile e Ambientale (DICEA)

**Gruppo di Lavoro:**
Prof.ssa Ing. Claudia Madiai (Responsabile)
Dott. Ing. Johann Facciorusso
Dott.ssa Ing. Elisa Gargini
Prof. Ing. Giovanni Vannucchi




*Distribuzione percentuale delle indagini CPT utilizzate*

Database - 225 prove CPT

**Liquefaction potential analyses** were conducted extensively over the whole studied area (Mugello) to draw up liquefaction hazard maps and improve the previous 3rd level microzonation study. Soil liquefaction analyses were performed in more than **200 sites** over the whole studied Mugello area in terms of liquefaction potential and cumulated settlements using three different CPT-based simplified methods:

-Boulanger and Idriss (2014),

-Juang et al. (2006)

-Robertson (2009).

Two important aspects were taken into account in the assessment:

The correction for the effects of fines content

**The correction of data from mechanical CPT's**

The **sleeve friction**, fs, has the greatest influence on the fine content and the plasticity index assessment and, consequently, on soil classification and liquefaction susceptibility estimation.
Furthermore, fs is affected by the greatest error when a mechanical penetrometer is used. For these reasons, electrical CPT-based methods applied to mechanical CPT data without any form of correction lead to erroneous estimates of liquefaction resistance and significantly non-conservative results, especially in case of intermediate soils are considered. To this regard, a procedure for correcting mechanical CPT data and providing modified equations and curves for liquefaction resistance estimation by means of CPT-based simplified methods has been proposed by Facciorusso et al. (2017).

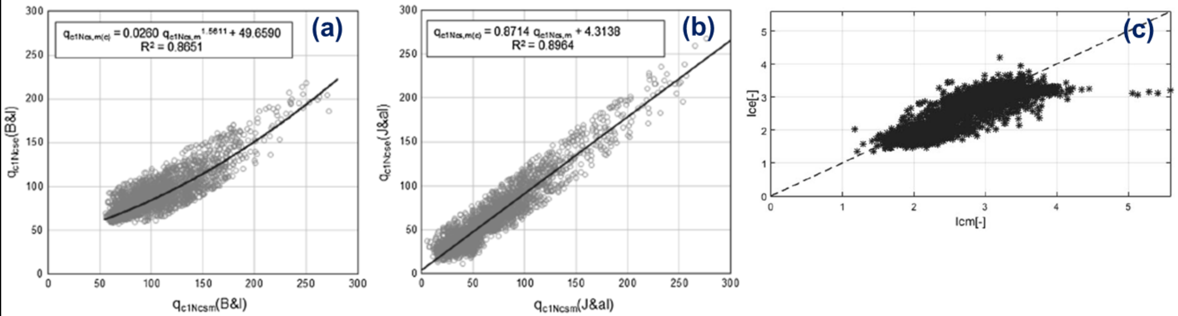
***Correzione dei risultati delle prove CPT meccaniche:***
Per i metodi di B&I (2014) e J&al (2006) le grandezze $(q_{c1N})_{cs}$ ed $I_c$ sono state corrette secondo le equazioni:

$$(q_{c1N})_{cs,EL} = 0.0260 \cdot (q_{c1N})_{cs,MEC}{}^{1.5611} + 49.6590 \quad (B\&I) \quad \mathbf{(a)}$$

$$(q_{c1N})_{cs,EL} = 0.8714 \cdot (q_{c1N})_{cs,MEC} + 4.3138 \quad (J\&al) \quad \mathbf{(b)}$$

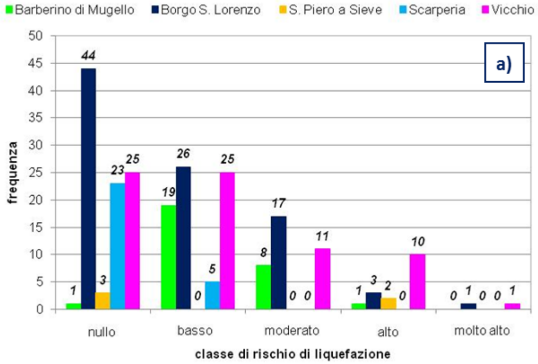
$$I_{c,EL} = 0.9464 \cdot I_{c,MEC} \quad \mathbf{(c)}$$

***Facciorusso et al. (2017)***

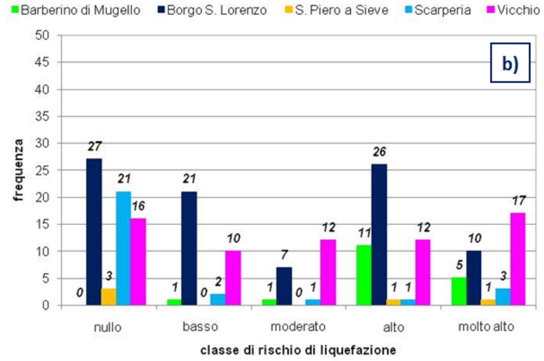



***Regressioni di $(q_{c1N})_{cs,EL}$ rispetto a $(q_{c1N})_{cs,MEC}$ ottenute per i metodi di B&I (a) e J&al (b) e regressione di $I_{c,EL}$ rispetto a $I_{c,MEC}$ (c)***

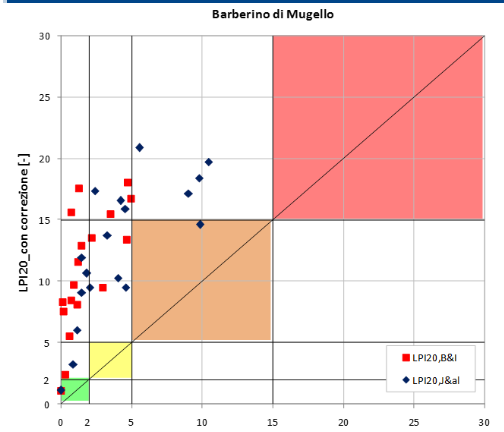
# CASE HISTORIES n.1

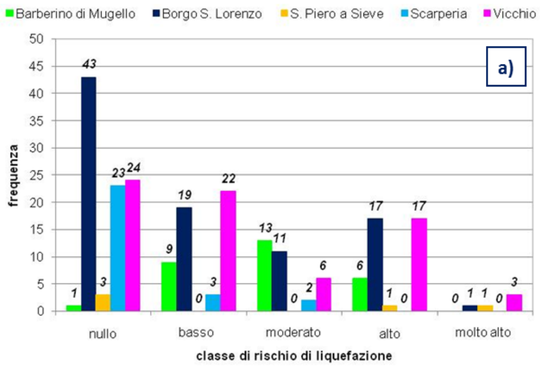



*Boulanger e Idriss (2014) – SENZA CORREZIONE*

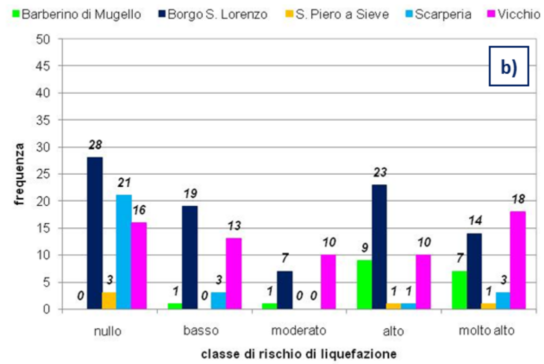



*Boulanger e Idriss (2014) – CON CORREZIONE*

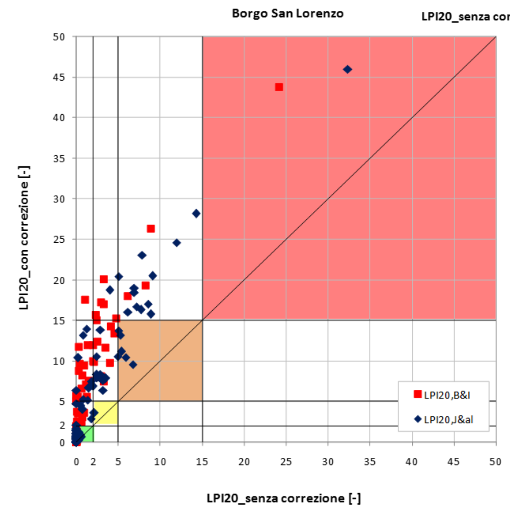



*Juang et al. (2006) – SENZA CORREZIONE*



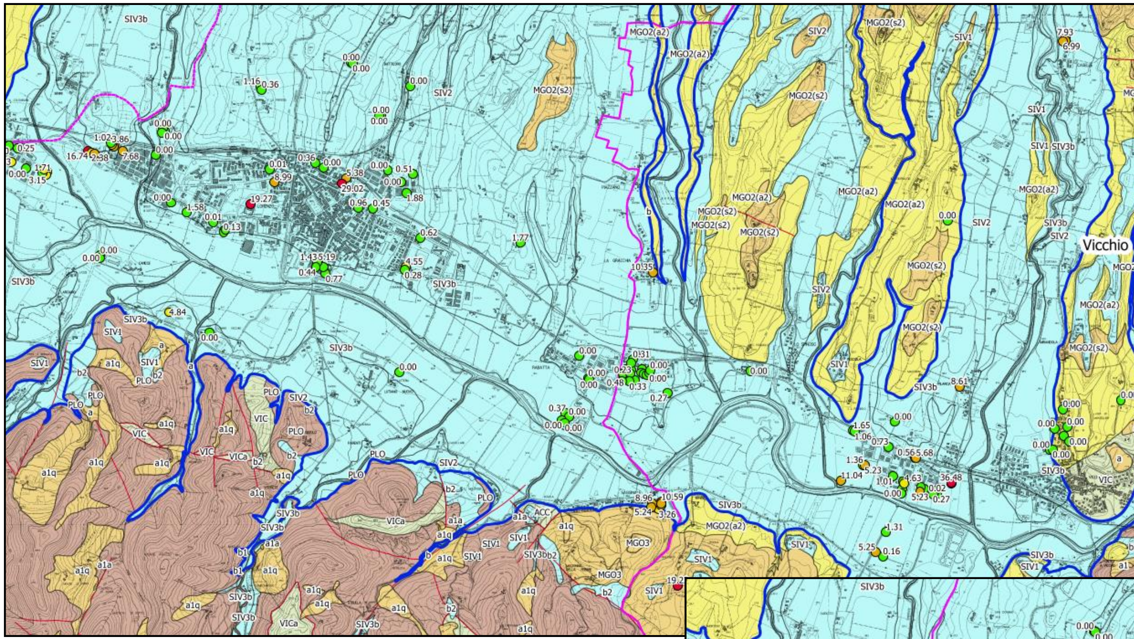

*Juang et al. (2006) – CON CORREZIONE*




*Da Madiai et alii, rapporto UNIFI-DICEA 2018*

Good agreement between B&I 2014 and Juang et al. 2006 methodology

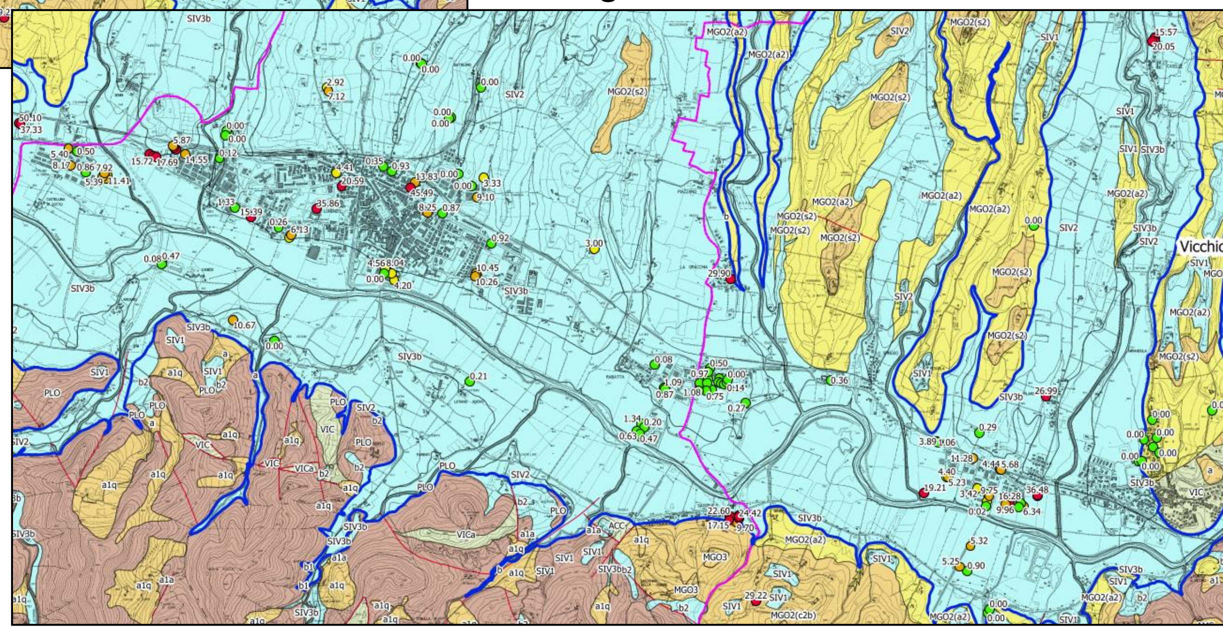
# CASE HISTORIES n.1




Juang at al. 2006 - LPI uncorrected index

## Map of liquefaction risk

Juang at al. 2006 - LPI corrected index




**Indici LPI Juang & Alii**

- *Indice da 0 a 2*
- *Indice da 2 a 5*
- *Indice da 5 a 15*
- *Indice maggiore di 15*

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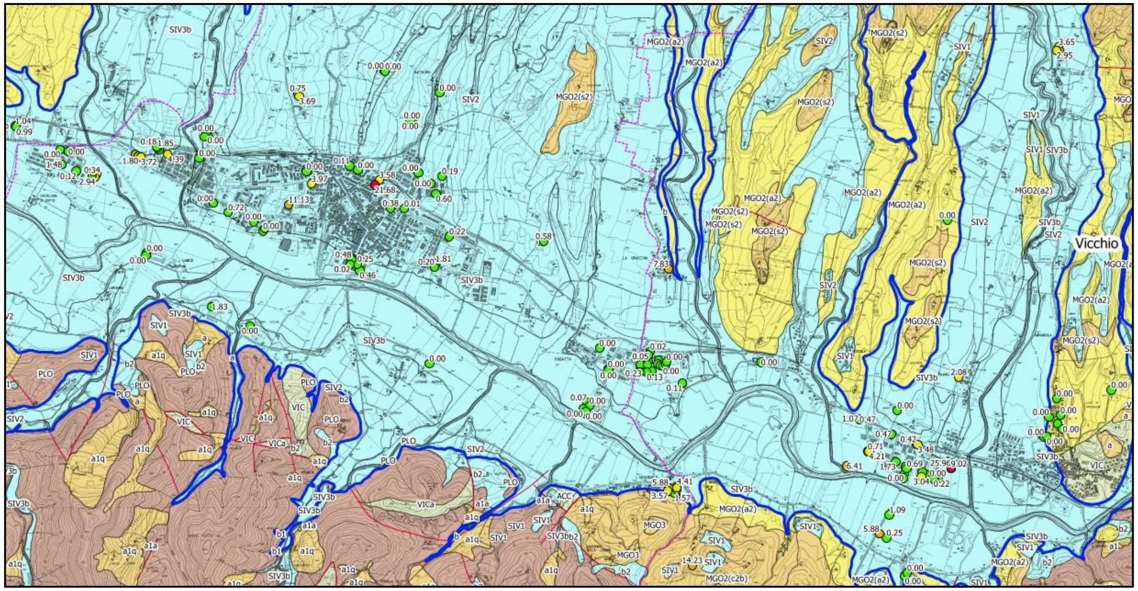
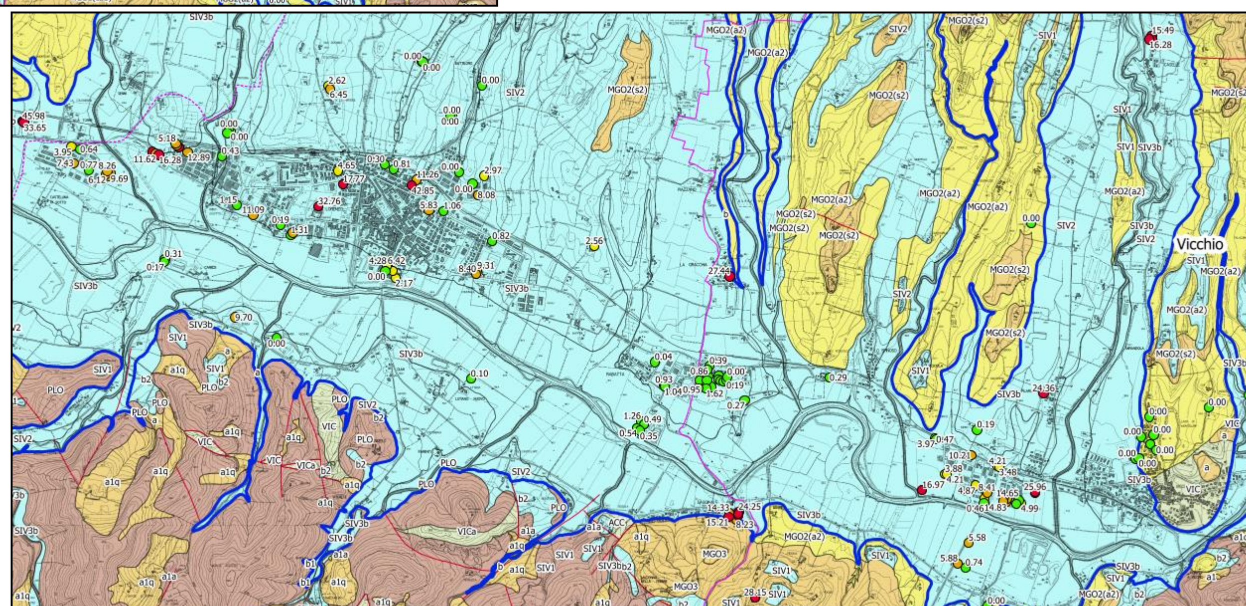
# CASE HISTORIES n.1




B & I 2014 - LPI uncorrected index

## Map of liquefaction risk

B&I 2014 - LPI corrected index




Indici LPI Boulanger & Idriss

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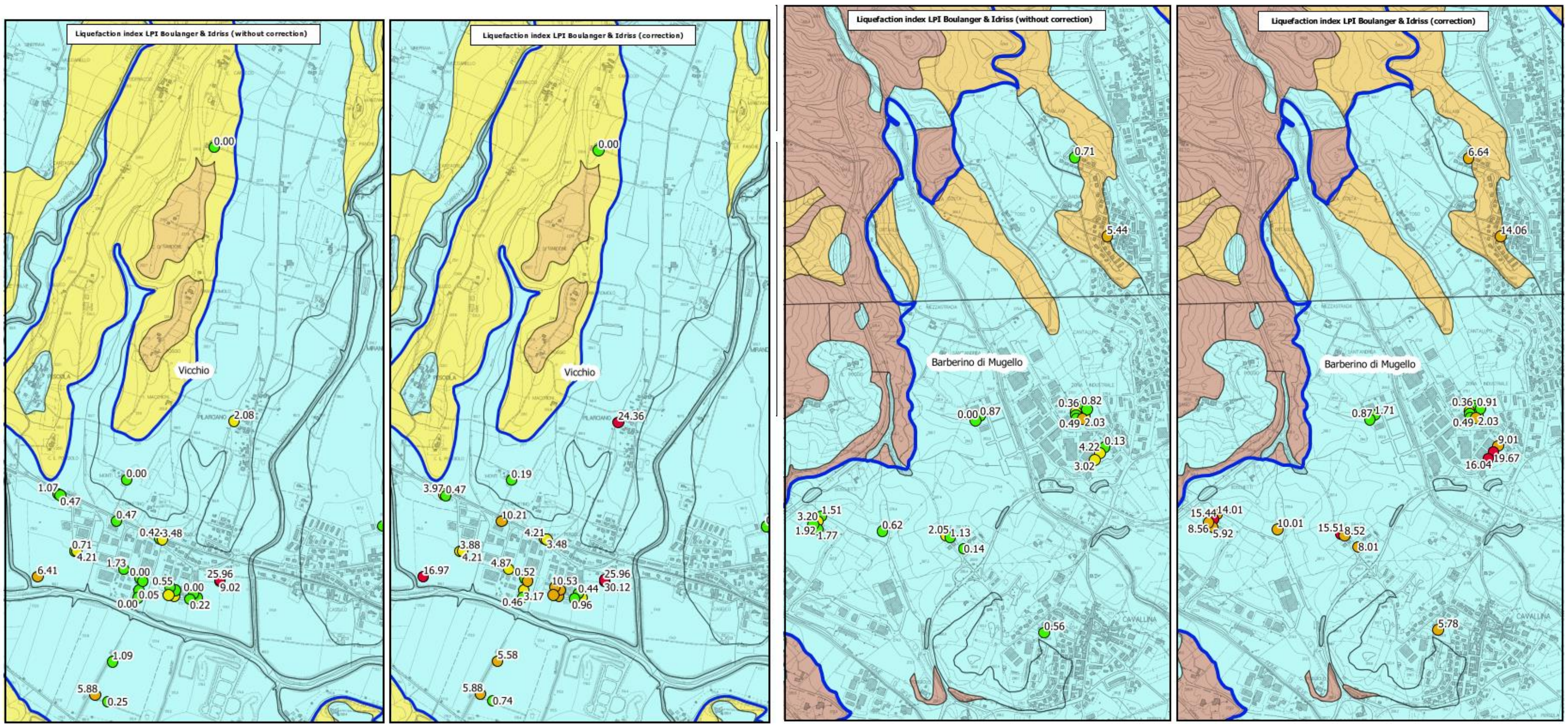
# Map of liquefaction risk




Maps of liquefaction hazard in terms of uncorrected and corrected LPI values provided for a test area in "Vicchio" and "Barberino" by using the Boulanger and Idriss (2014) method and assuming Ic,lim = 2.6.

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# CASE HISTORIES n.2

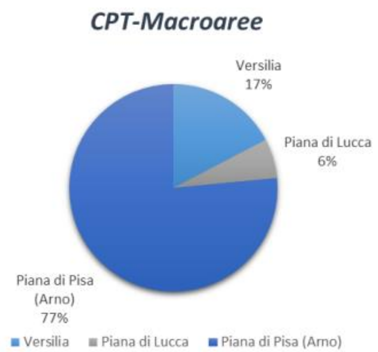
Regione Toscana

UNIVERSITÀ DI PISA

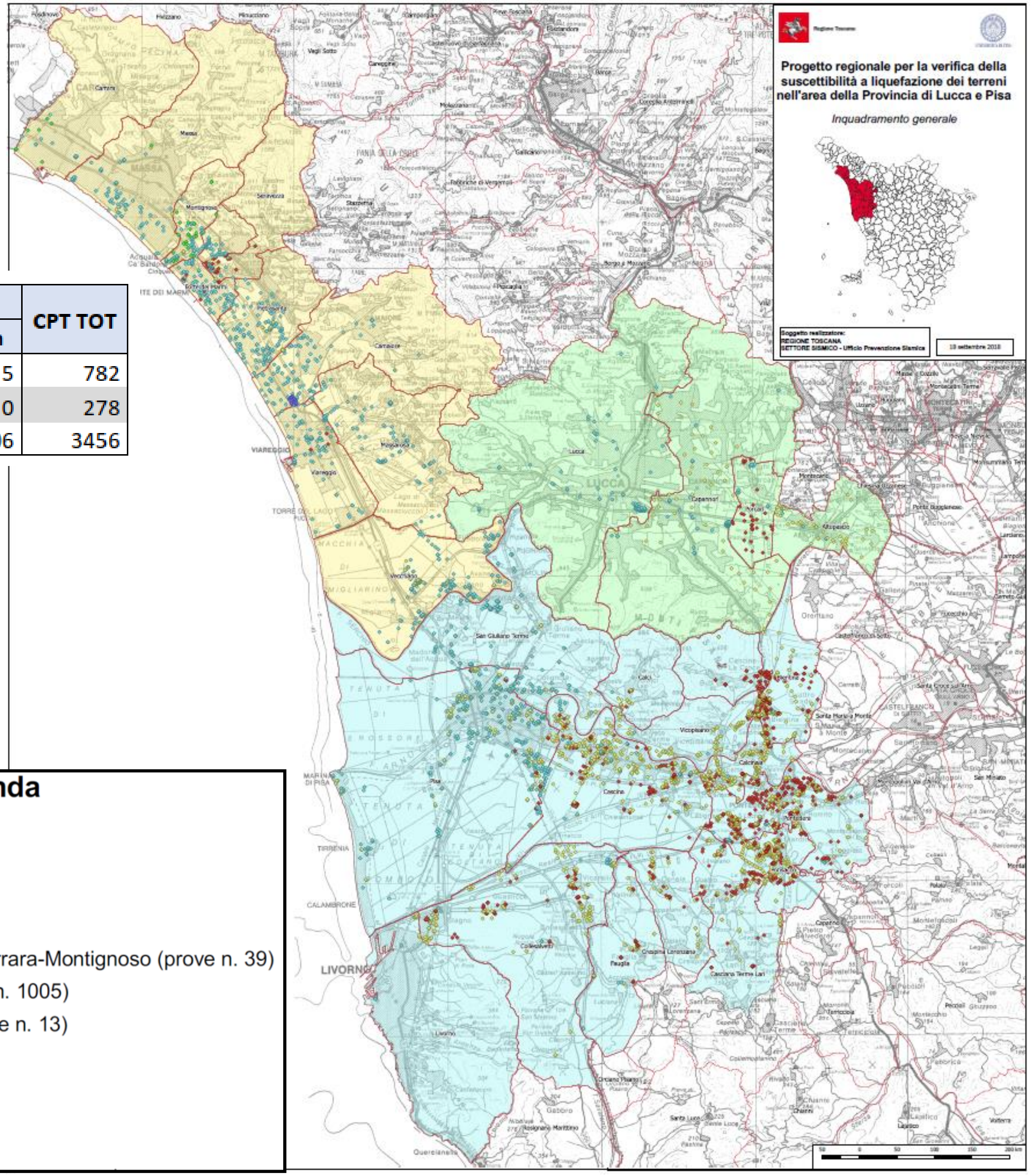
## Progetto regionale per la verifica della suscettibilità a liquefazione dei terreni nell'area della Provincia di Lucca e Pisa

| Macroarea | Depth (m) | | | | | | CPT TOT |
|---|---|---|---|---|---|---|---|
| | 0-5 m | 5-8 m | 8-10 m | 10-15 m | 15-20 m | > 20 m | |
| Versilia | 70 | 246 | 267 | 138 | 56 | 5 | 782 |
| Piana di Lucca | 58 | 111 | 68 | 33 | 8 | 0 | 278 |
| Piana di Pisa (Arno) | 156 | 561 | 1691 | 592 | 250 | 206 | 3456 |

*Da Lo Presti et alii, rapporto UNIPI-DICI 2018*




Lo Presti et al. 2017




**Legenda**

Fonte archivio indagini CPT

- DB Lamma (prove n. 1963)
- DB Provincia (prove n. 1523)
- DB Microzonazione Massa-Carrara-Montignoso (prove n. 39)
- DB Lamma solo grafici (prove n. 1005)
- DB MS Regione Toscana (prove n. 13)
- confini comunali
- Sub progetto Versilia
- Sub progetto Lucca
- Sub progetto Pisa

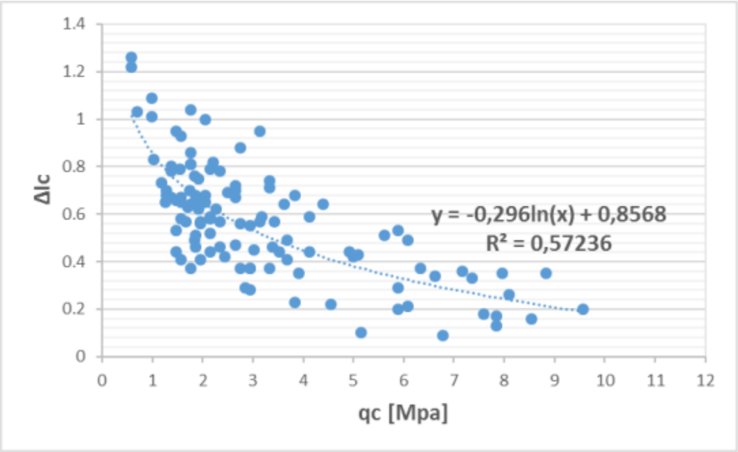
# CASE HISTORIES n.2

Soil liquefaction analyses were performed in more than 4000 sites over the “Versilia” area, “Pisa” Plan and “Lucca” area in terms of liquefaction potential (LPI) using three different CPT-based simplified methods, namely Boulanger and Idriss (2014), Juang et al. (2006) and Robertson-Write (1998).

<u>Input parameters</u>: Vn= 50 years; Cu=1; soil-type = C; different PGA for town; M=5.5

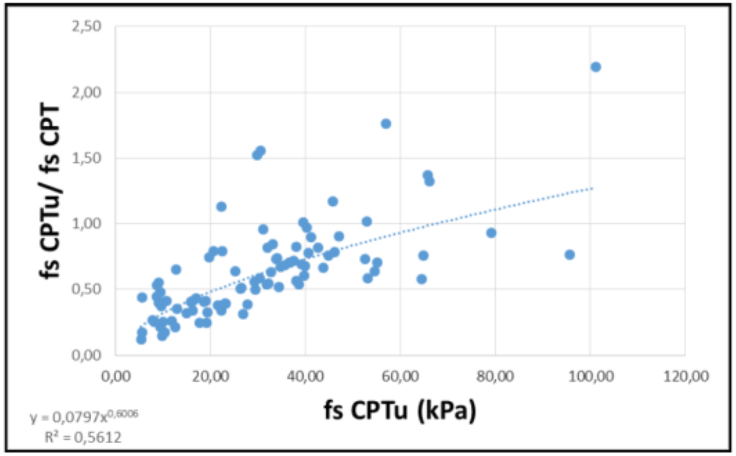
LPI valuation – Iwasaki et al. 1978

Ic correction (Meisina et all. 2017, Lo Presti et al. 2017) and correction (Francesconi, 2015)




$$\Delta Ic = -0.296 \ln(qc) + 0.8568$$

$$Ic\ (correct) = Ic(Robertson,\ 1990) - \Delta Ic$$



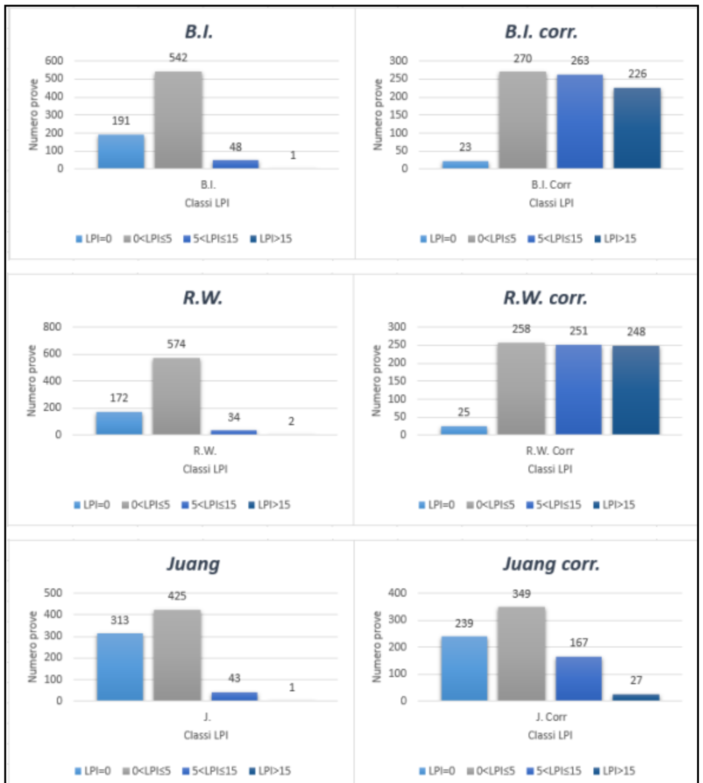

$$f_{s\,CPTu} = (0.0797 \times f_{s\,CPTm})^{2,504}$$

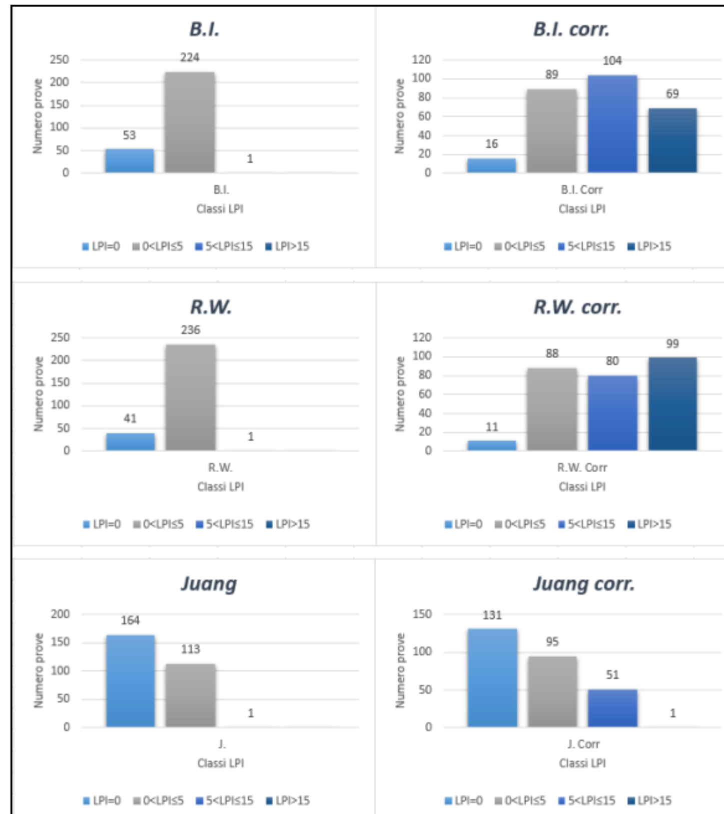
# CASE HISTORIES n.2

## LPI - STATISTICAL DISTRIBUTION

| MACROAREA: VERSILIA | | | | | | |
|---|---|---|---|---|---|---|
| LPI Iwasaki | B.I. | B.I. Corr | R.W. | R.W. Corr | J. | J. Corr |
| LPI=0 | 191 | 23 | 172 | 25 | 313 | 239 |
| 0<LPI≤5 | 542 | 270 | 574 | 258 | 425 | 349 |
| 5<LPI≤15 | 48 | 263 | 34 | 251 | 43 | 167 |
| LPI>15 | 1 | 226 | 2 | 248 | 1 | 27 |

| MACROAREA: PIANA DI LUCCA | | | | | | |
|---|---|---|---|---|---|---|
| LPI Iwasaki | B.I. | B.I. Corr | R.W. | R.W. Corr | J. | J. Corr |
| LPI=0 | 53 | 16 | 41 | 11 | 164 | 131 |
| 0<LPI≤5 | 224 | 89 | 236 | 88 | 113 | 95 |
| 5<LPI≤15 | 1 | 104 | 1 | 80 | 1 | 51 |
| LPI>15 | 0 | 69 | 0 | 99 | 0 | 1 |

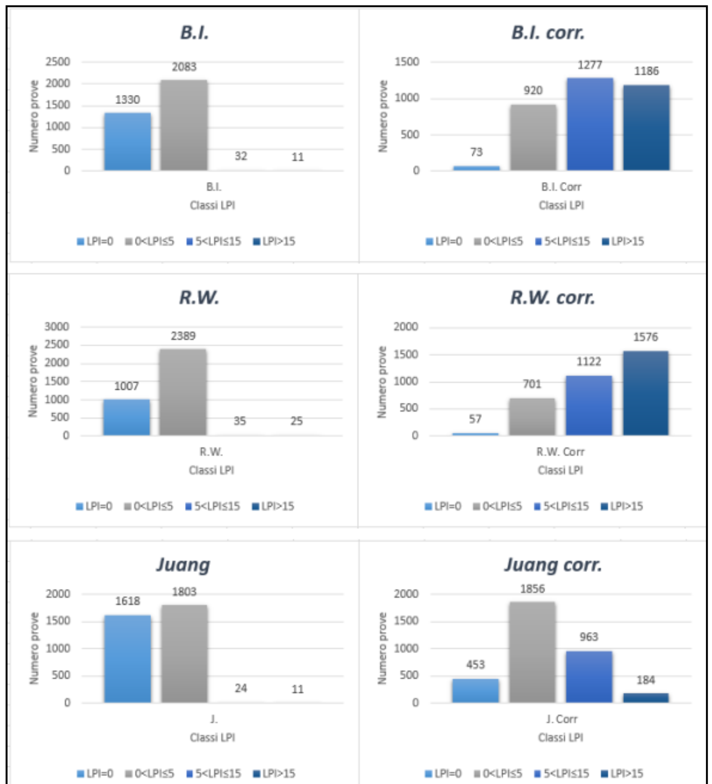



*Da Lo Presti et alii, rapporto UNIPI-DICI 2018*

# LPI - STATISTICAL DISTRIBUTION

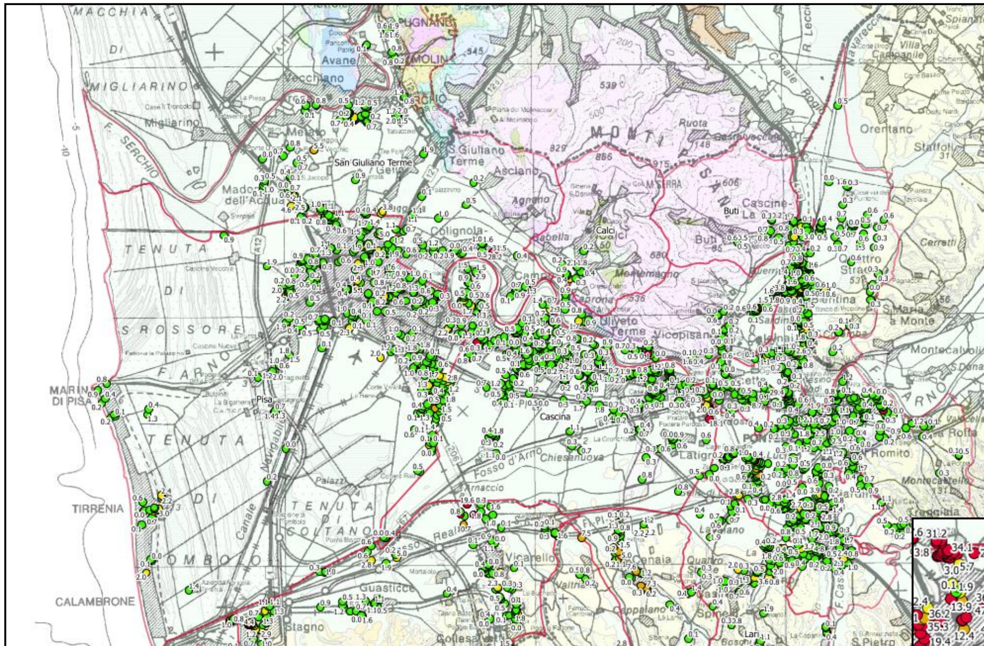
| MACROAREA: PIANA DI PISA | | | | | | |
|---|---|---|---|---|---|---|
| LPI $_{Iwasaki}$ | B.I. | B.I. Corr | R.W. | R.W. Corr | J. | J. Corr |
| LPI=0 | 1330 | 73 | 1007 | 57 | 1618 | 453 |
| 0<LPI≤5 | 2083 | 920 | 2389 | 701 | 1803 | 1856 |
| 5<LPI≤15 | 32 | 1277 | 35 | 1122 | 24 | 963 |
| LPI>15 | 11 | 1186 | 25 | 1576 | 11 | 184 |

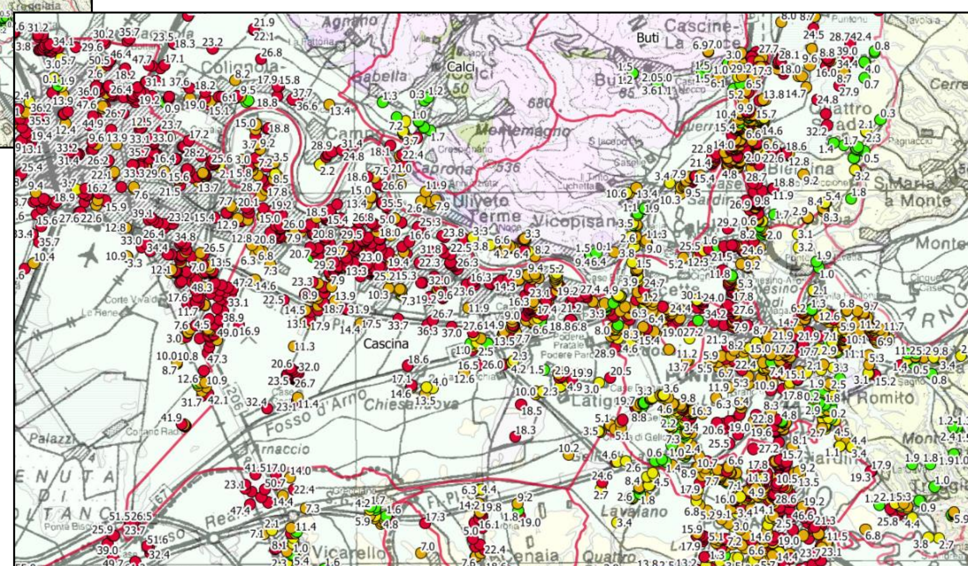



*Da Lo Presti et alii, rapporto UNIPI-DICI 2018*

# Map of liquefaction risk (Pisa plan)

LPI evaluation - Robertson-Write (1998)



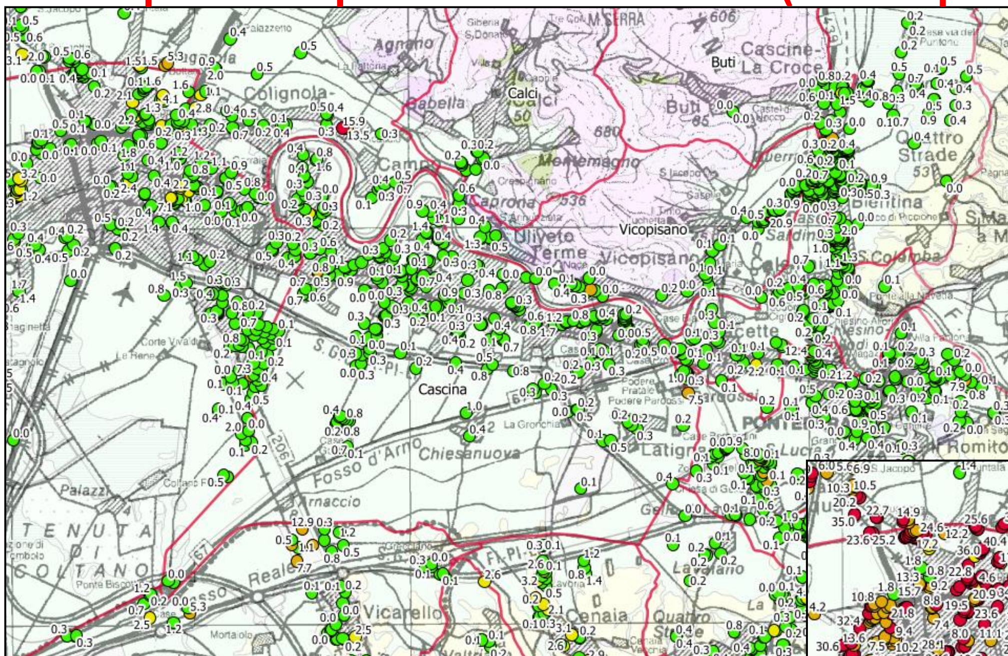

**Legenda**

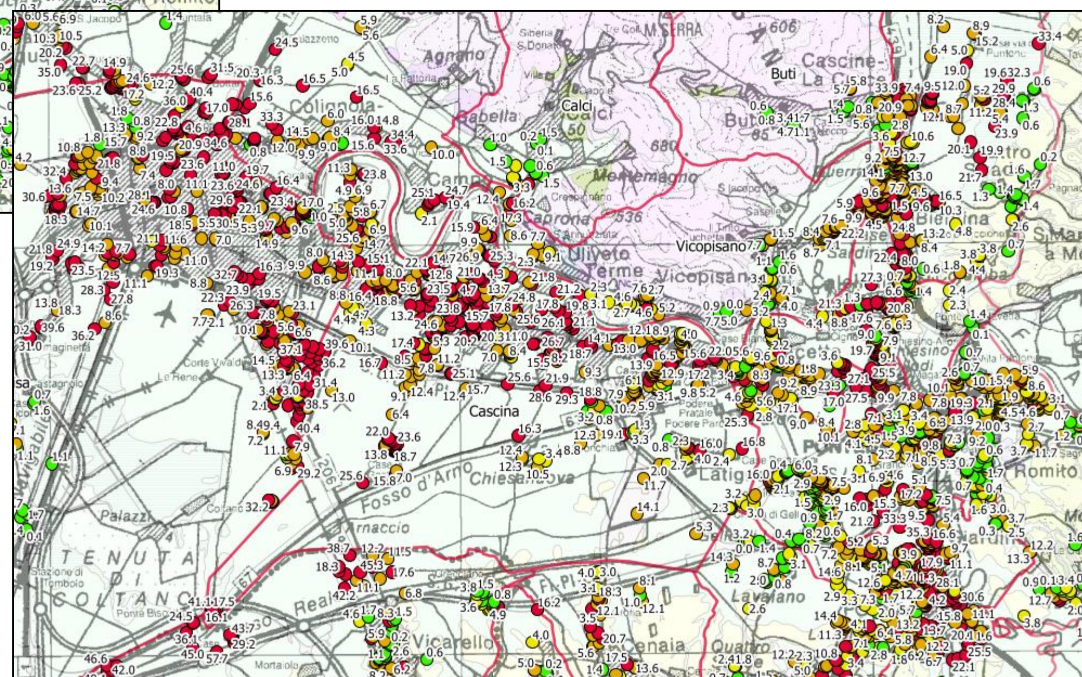
**Classificazione LPI metodo R&W**

- classe da 0 a 2
- classe da 2 a 5
- classe da 5 a 15
- classe maggiore di 15
- Sub progetto PISA

# Map of liquefaction risk (Pisa plan)

LPI evaluation – Boulanger & Idriss (2014)



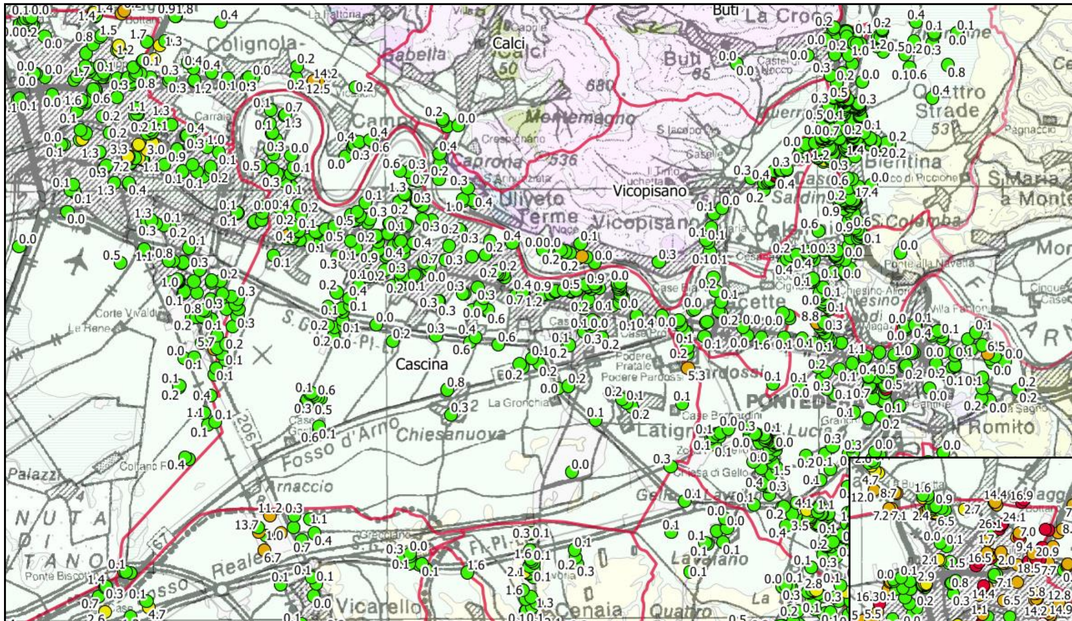




**Legenda**

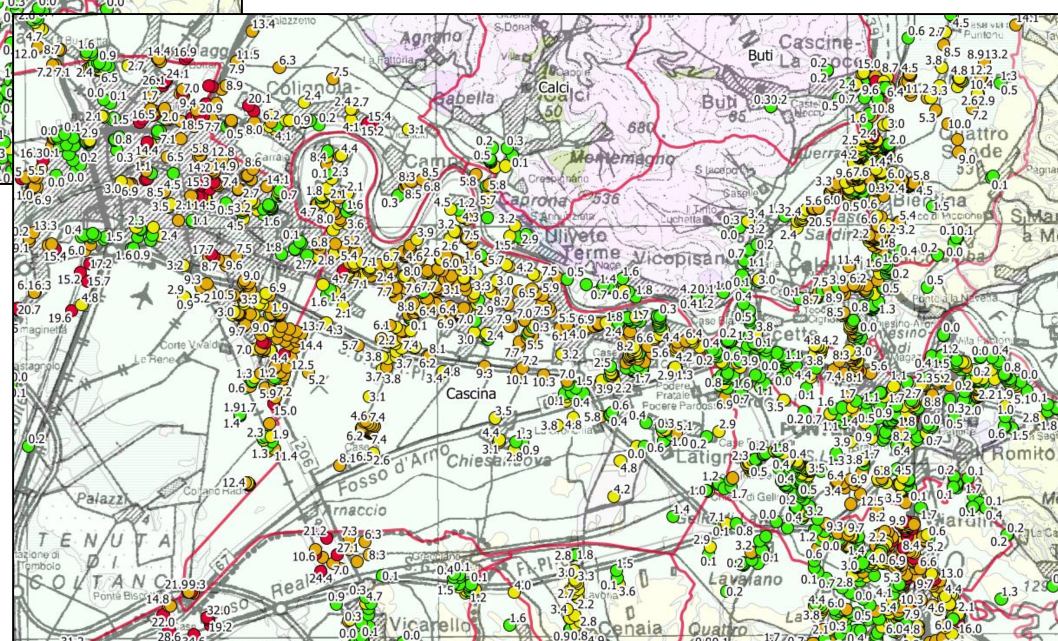
Classificazione LPI metodo B&I

- classe da 0 a 2
- classe da 2 a 5
- classe da 5 a 15
- classe maggiore di 15
- Sub progetto PISA

# Map of liquefaction risk (Pisa plan)



LPI evaluation – Juang et al. (2006)

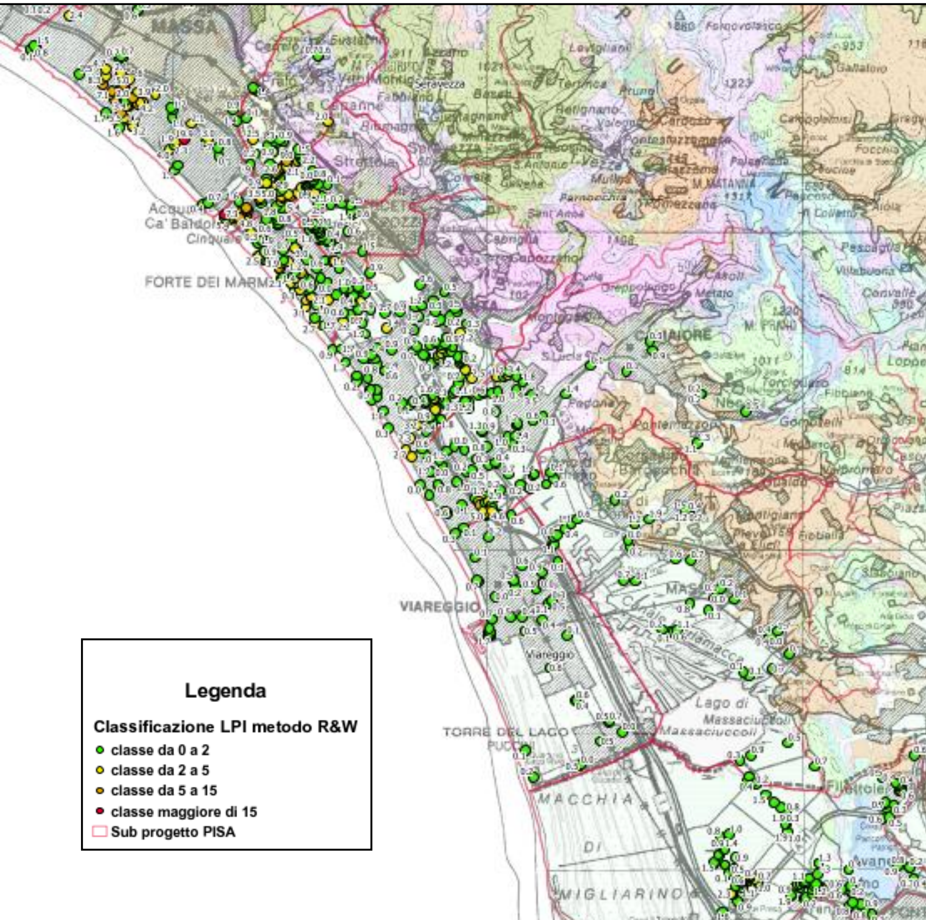


**Legenda**

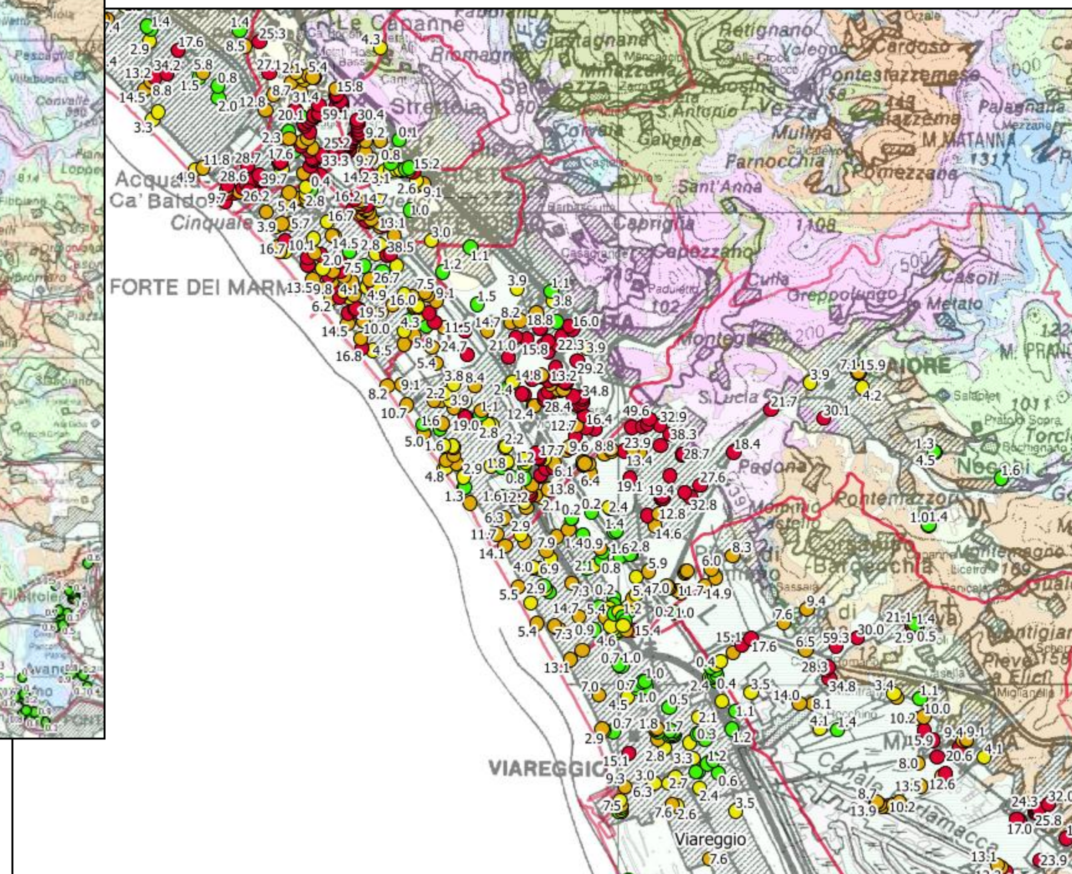
**Classificazione LPI metodo J&AL**

- classe da 0 a 2
- classe da 2 a 5
- classe da 5 a 15
- classe maggiore di 15
- Sub progetto PISA

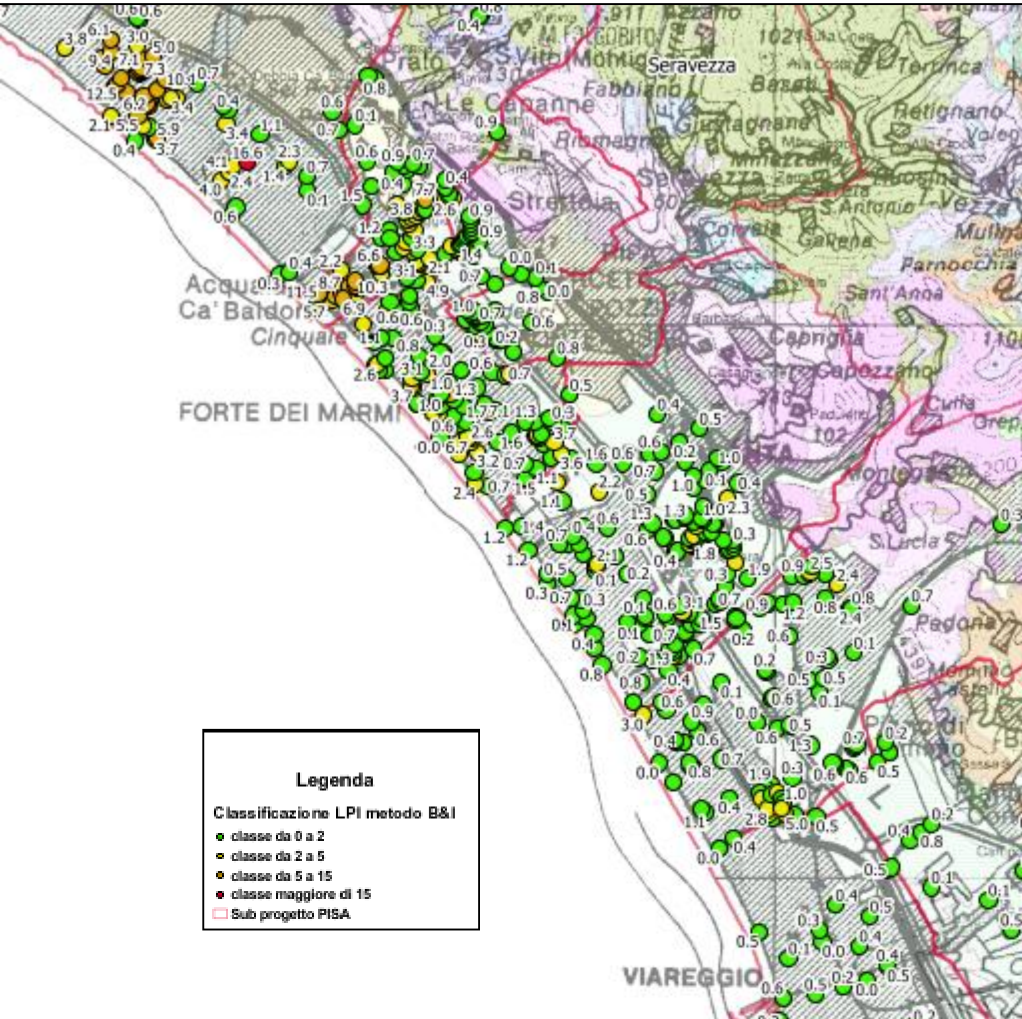
# Map of liquefaction risk (Versilia area)



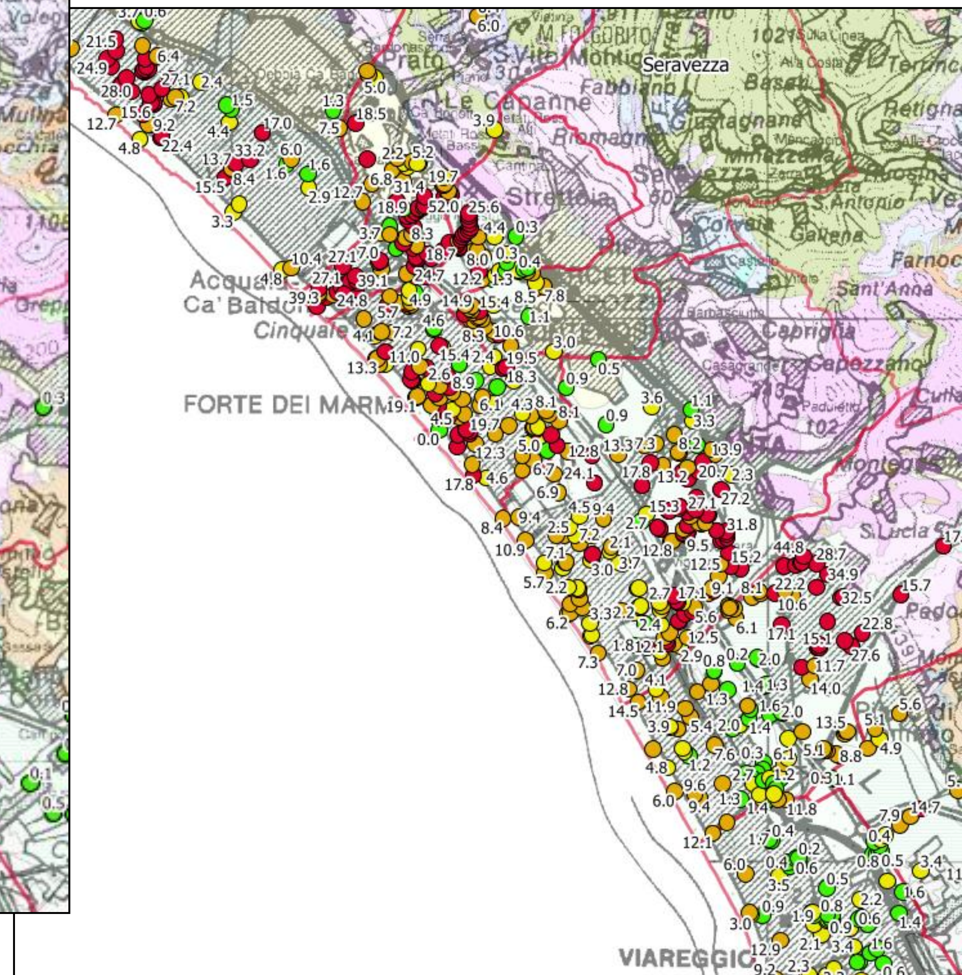

LPI evaluation - Robertson-Write (1998)



# Map of liquefaction risk (Versilia area)

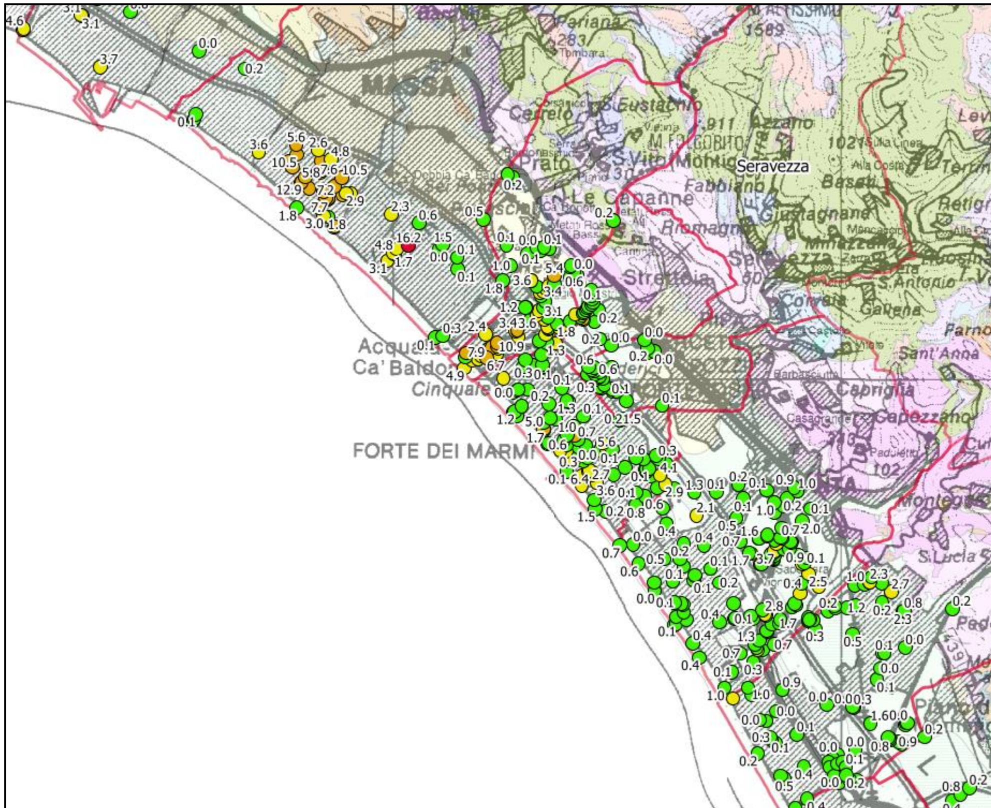


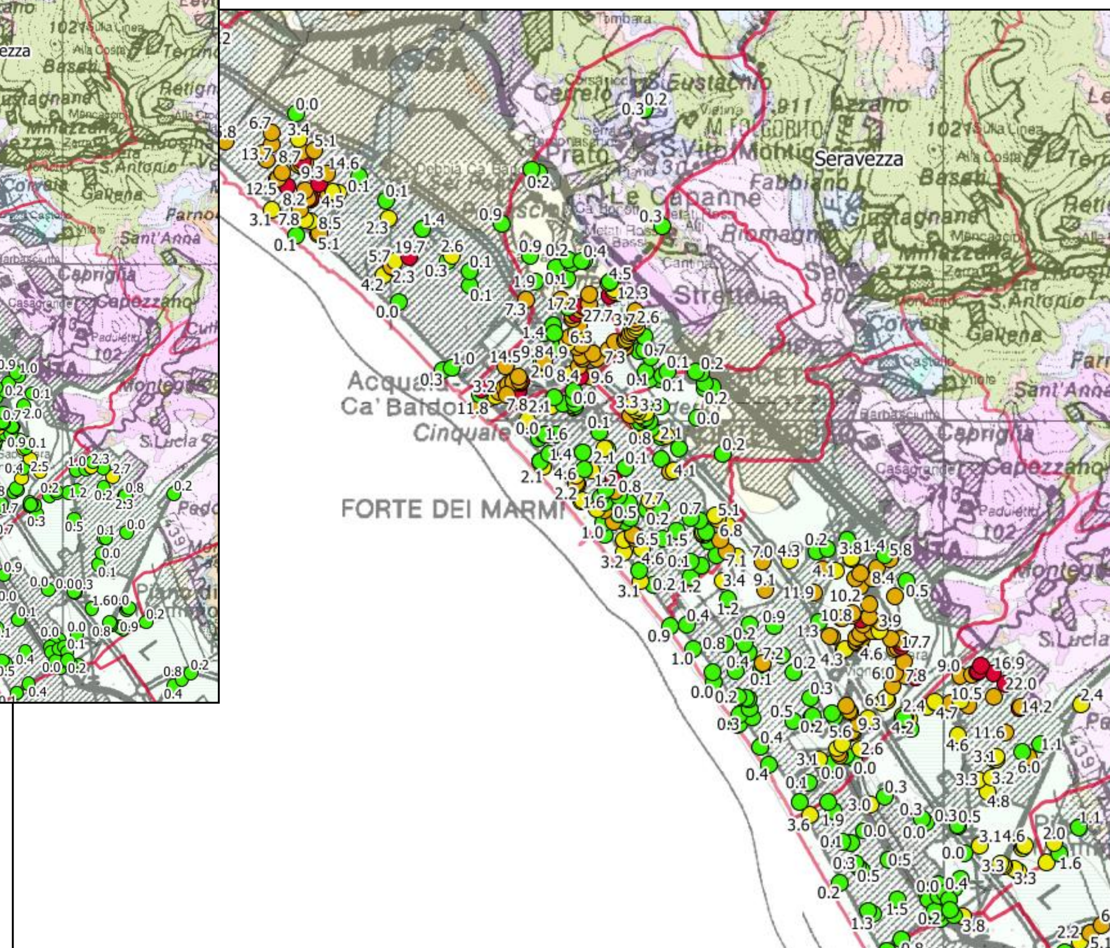

LPI evaluation – Boulanger & Idriss (2014)



# Map of liquefaction risk (Versilia area)

LPI evaluation – Juang et al. (2006)



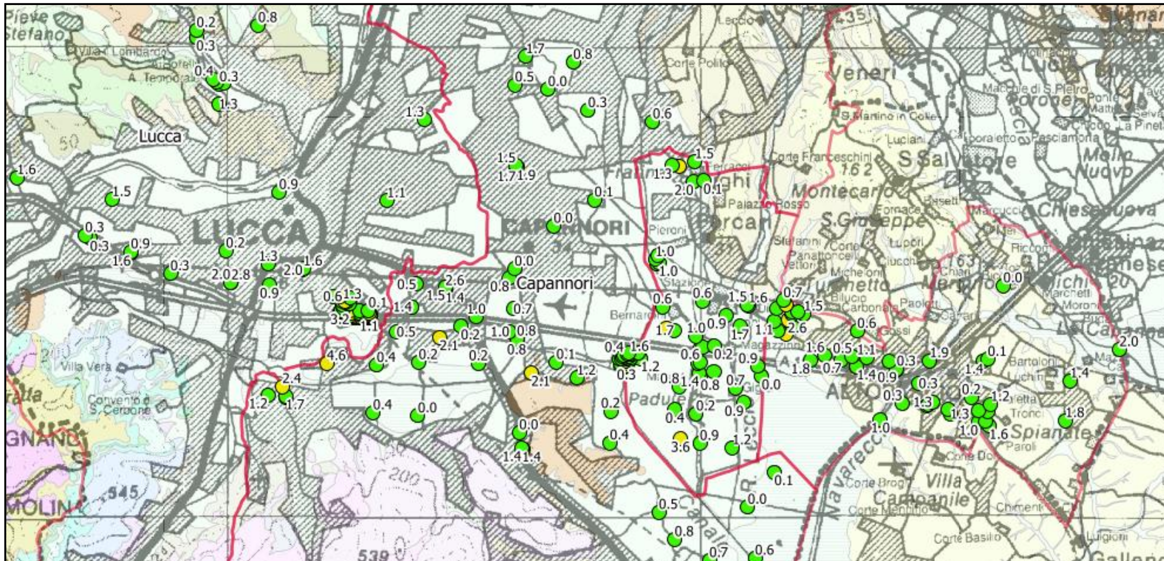




**Legenda**

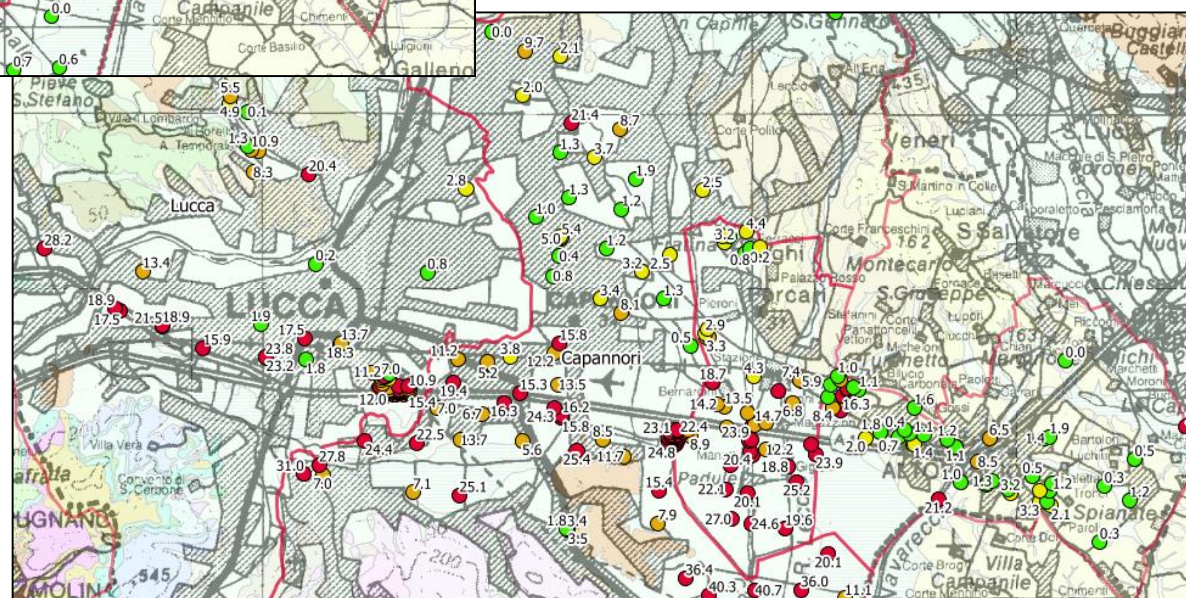
**Classificazione LPI metodo J&AL**

- classe da 0 a 2
- classe da 2 a 5
- classe da 5 a 15
- classe maggiore di 15
- Sub progetto VERSILIA

# Map of liquefaction risk (Lucca plan)



LPI evaluation - Robertson-Write (1998)

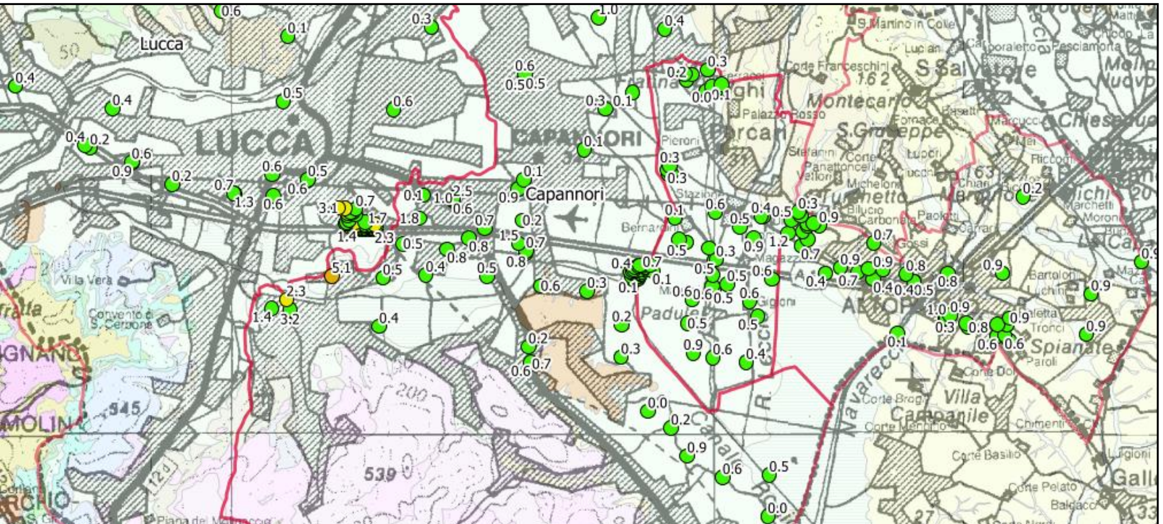


**Legenda**

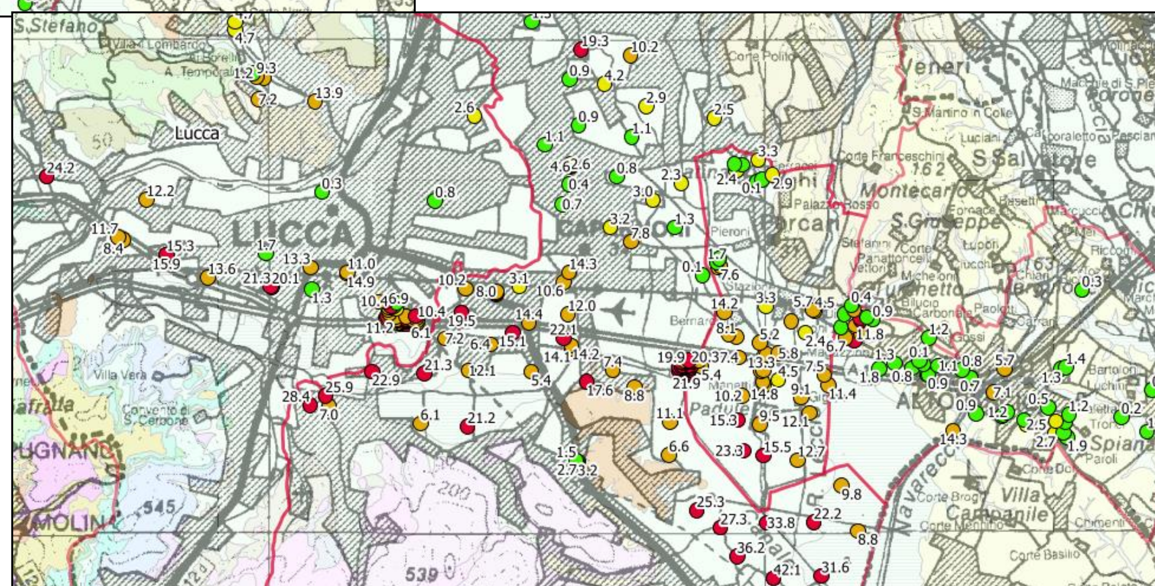
**Classificazione LPI metodo R&W**

- classe da 0 a 2
- classe da 2 a 5
- classe da 5 a 15
- classe maggiore di 15
- Sub progetto LUCCA

# Map of liquefaction risk (Lucca plan)




LPI evaluation – Boulanger & Idriss (2014)




**Legenda**

**Classificazione LPI metodo B&I**

- classe da 0 a 2
- classe da 2 a 5
- classe da 5 a 15
- classe maggiore di 15
- Sub progetto LUCCA

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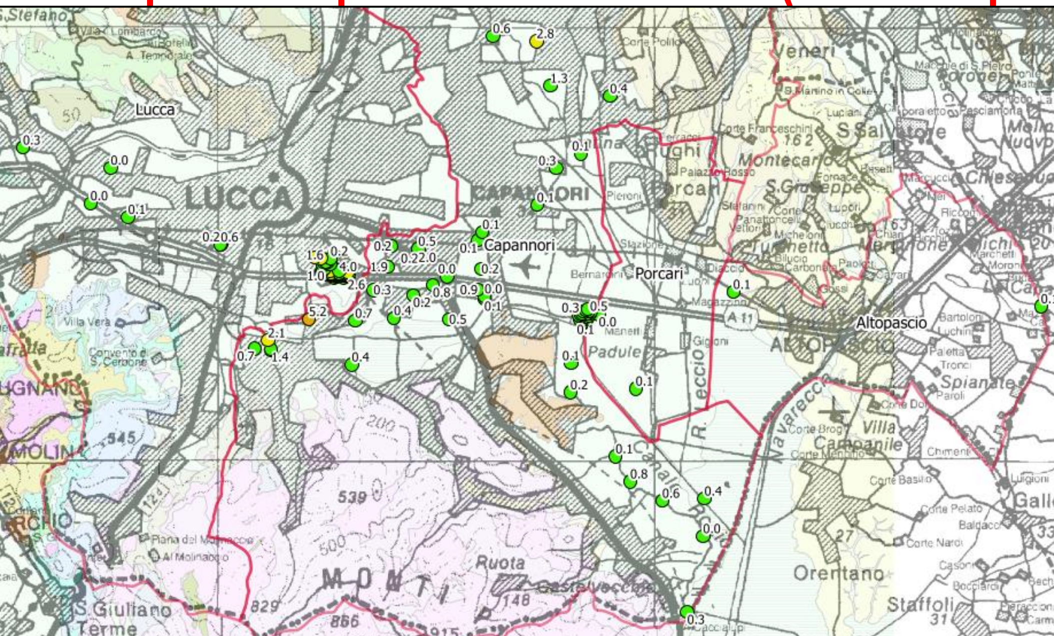
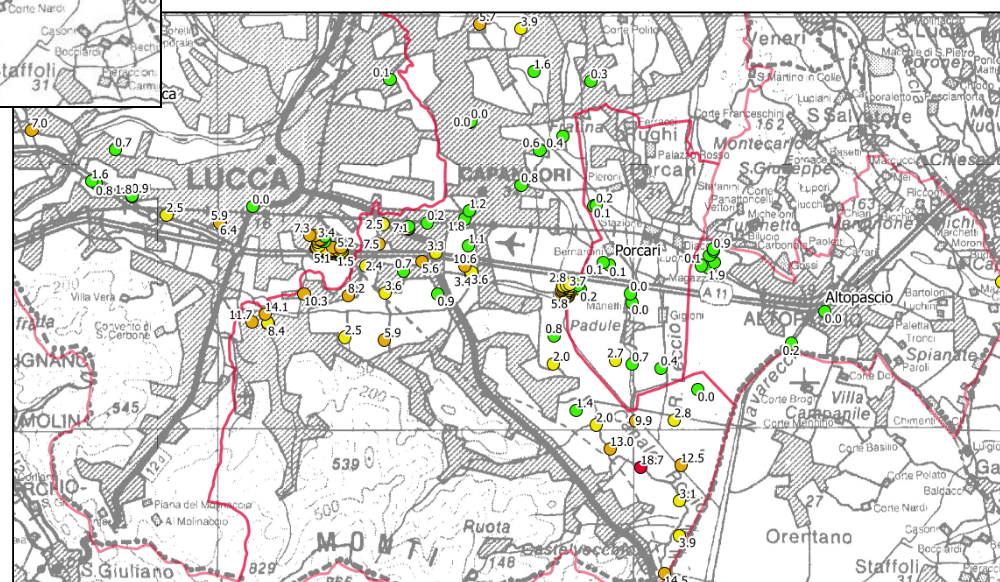
**CASE HISTORIES n.2**

# Map of liquefaction risk (Lucca plan)




LPI evaluation – Juang et al. (2006)




**Legenda**

**Classificazione LPI metodo J&AL corretto**
- classe da 0 a 2
- classe da 2 a 5
- classe da 5 a 15
- classe maggiore di 15
- Sub progetto LUCCA

# Discussion and final remarks

1) The simplified CPT-based procedures selected for these study all gave different results in terms of LPI, overall for soils with intermediate grain-size distribution (clean sands / clays). These differences can be addressed principally to the correction factor proposed for the estimation of the equivalent clean sand cone tip resistance that is generally based on the empirical assessment of the fines content

*It's recommended to use multiple methods in order to evaluate the dispersion*

2) The influence of correction (CPTe/CPTm) is significant and the liquefaction hazard evaluated at most of the investigated sites changes from low to high or very high

*It's recommended to use CPTu-CPTe test to evaluate the LPI*

3) The B&I (2014) e R&W (1998) methods provide similar results while Juang et al. (2006) provides less conservative results (but closer to CPTe LPI results and ….). The application of the correction to the "Juang" methods leads to lower increased LPI values compared to other methods.

*It's advisable to use Juang et al. (2006) method for LPI*

4) The use of corrections to standard methodology is being studied by the Pisa University (Scientific Resp. Prof. Diego Lo Presti)

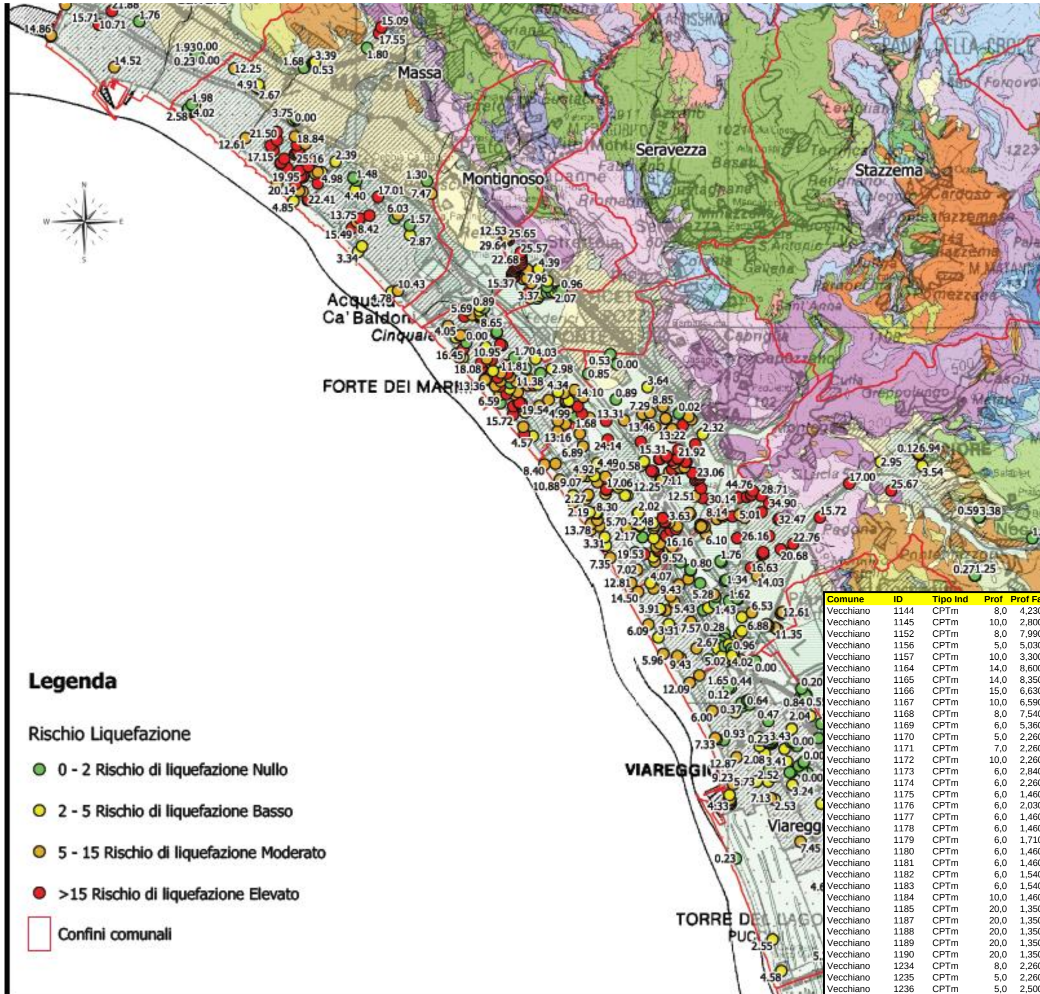
# CPT Database of the Tuscany Region

**REGIONE TOSCANA**

**Direzione Ambiente ed Energia**
**Settore Sismica Regionale - Prevenzione Sismica**

# LIQUEFACTION DATABASE

*http://www.regione.toscana.it/-/risultati-indagini-e-studi-di-microzonazione-sismica*




## CPT REGIONAL DATABASE OF LIQUEFACTION RISK

LPI corrected values

| Comune | ID | Tipo Ind | Prof | Prof Falda | a_max (g) | LPI10_B&I | LPI10_B&I C | LPI10_R&W | LPI10_R&W C | LPI10_J | LPI10_J C | Cod |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vecchiano | 1144 | CPTm | 8,0 | 4,230000000000000 | 0,181000000000000 | 0,000000000000000 | 0,184394030000000 | 0 | 0,429549682000000 | 0 | 0 | 00423 |
| Vecchiano | 1145 | CPTm | 10,0 | 2,800000000000000 | 0,181000000000000 | 0,318319444000000 | 8,597666492000000 | 0.758772896 | 9,747793176000000 | 0.103585593 | 0.464265318 | 00068 |
| Vecchiano | 1152 | CPTm | 8,0 | 7,990000000000000 | 0,181000000000000 | 0,000000000000000 | 0,000000000000000 | 0 | 0,494617910000000 | 0 | 0 | 00422 |
| Vecchiano | 1156 | CPTm | 5,0 | 5,030000000000000 | 0,181000000000000 | 0,232653765000000 | 0,721568349000000 | 0.128425499 | 1,418315214000000 | 0 | 0 | 01524 |
| Vecchiano | 1157 | CPTm | 10,0 | 3,300000000000000 | 0,181000000000000 | 0,284904261000000 | 3,124109933000000 | 1.147382283 | 3,918574176000000 | 0 | 0 | 00897 |
| Vecchiano | 1164 | CPTm | 14,0 | 8,600000000000000 | 0,181000000000000 | 0,409357576000000 | 4,431925320000000 | 0.756220113 | 18,873232760000000 | 0 | 0 | 00721 |
| Vecchiano | 1165 | CPTm | 14,0 | 8,350000000000000 | 0,181000000000000 | 0,576204618000000 | 3,625242702000000 | 0.871444072 | 15,958673550000000 | 0 | 0 | 00720 |
| Vecchiano | 1166 | CPTm | 15,0 | 6,630000000000000 | 0,181000000000000 | 0,000000000000000 | 6,944143268000000 | 0.260139247 | 18,767393070000000 | 0 | 0 | 00525 |
| Vecchiano | 1167 | CPTm | 10,0 | 6,590000000000000 | 0,181000000000000 | 0,510956974000000 | 0,736381536000000 | 0.553932184 | 2,716139698000000 | 0 | 0 | 01139 |
| Vecchiano | 1168 | CPTm | 8,0 | 7,540000000000000 | 0,181000000000000 | 0,000000000000000 | 0,000000000000000 | 0 | 0,000000000000000 | 0 | 0 | 00424 |
| Vecchiano | 1169 | CPTm | 6,0 | 5,360000000000000 | 0,181000000000000 | 0,206860662000000 | 1,545199317000000 | 0.094681849 | 3,999792026000000 | 0 | 0 | 01195 |
| Vecchiano | 1170 | CPTm | 5,0 | 2,260000000000000 | 0,181000000000000 | 0,000000000000000 | 1,904701259000000 | 0 | 1,477378377000000 | 0 | 0 | 00589 |
| Vecchiano | 1171 | CPTm | 7,0 | 2,260000000000000 | 0,181000000000000 | 0,234791287000000 | 7,813276512000000 | 1.319131432 | 8,938075818000000 | 0.002863548 | 0.366671712 | 01047 |
| Vecchiano | 1172 | CPTm | 10,0 | 2,260000000000000 | 0,181000000000000 | 0,955941980000000 | 15,877457580000000 | 1.177702855 | 19,345073440000000 | 0.327622615 | 3.993266677 | 01046 |
| Vecchiano | 1173 | CPTm | 6,0 | 2,840000000000000 | 0,181000000000000 | 0,460700447000000 | 4,032539829000000 | 1.204348492 | 5,429115621000000 | 0 | 0.014425123 | 01048 |
| Vecchiano | 1174 | CPTm | 6,0 | 2,260000000000000 | 0,181000000000000 | 0,460700447000000 | 2,301814787000000 | 1.169605064 | 2,453016854000000 | 0 | 0 | 01045 |
| Vecchiano | 1175 | CPTm | 6,0 | 1,460000000000000 | 0,181000000000000 | 0,622732680000000 | 3,134076354000000 | 0.789550717 | 2,554085075000000 | 0.062740848 | 0.062740848 | 01044 |
| Vecchiano | 1176 | CPTm | 6,0 | 2,030000000000000 | 0,181000000000000 | 0,460700447000000 | 7,943703310000000 | 0.722759778 | 9,342653566000000 | 0 | 2.067306603 | 01049 |
| Vecchiano | 1177 | CPTm | 6,0 | 1,460000000000000 | 0,181000000000000 | 1,218619088000000 | 8,644394984000000 | 2.25868305 | 9,651094549000000 | 0.620143577 | 1.811881524 | 01050 |
| Vecchiano | 1178 | CPTm | 6,0 | 1,460000000000000 | 0,181000000000000 | 0,988370908000000 | 6,011283398000000 | 1.570955489 | 6,545200314000000 | 0.515429073 | 1.247104728 | 01043 |
| Vecchiano | 1179 | CPTm | 6,0 | 1,710000000000000 | 0,181000000000000 | 0,000000000000000 | 1,323818967000000 | 0 | 1,375823464000000 | 0 | 0 | 00325 |
| Vecchiano | 1180 | CPTm | 6,0 | 1,460000000000000 | 0,181000000000000 | 1,390626668000000 | 5,156165925000000 | 1.55837207 | 5,541100402000000 | 0.80430721 | 1.442271845 | 01051 |
| Vecchiano | 1181 | CPTm | 6,0 | 1,460000000000000 | 0,181000000000000 | 1,466295402000000 | 7,514359767000000 | 1.84109073 | 8,065525796000000 | 0.814267909 | 1.48396801 | 01052 |
| Vecchiano | 1182 | CPTm | 6,0 | 1,540000000000000 | 0,181000000000000 | 0,000000000000000 | 1,605588368000000 | 0 | 1,643767386000000 | 0 | 0 | 00854 |
| Vecchiano | 1183 | CPTm | 6,0 | 1,540000000000000 | 0,181000000000000 | 0,000000000000000 | 0,627528611000000 | 0 | 0,409006552000000 | 0 | 0 | 00855 |
| Vecchiano | 1184 | CPTm | 10,0 | 1,460000000000000 | 0,181000000000000 | 0,943799122000000 | 10,252333240000000 | 0.855696597 | 11,724304200000000 | 0.73708774 | 2.222495058 | 00310 |
| Vecchiano | 1185 | CPTm | 20,0 | 1,350000000000000 | 0,181000000000000 | 0,971338295000000 | 14,111439820000000 | 1.321294476 | 19,060894710000000 | 0.543258355 | 7.243271052 | 00745 |
| Vecchiano | 1187 | CPTm | 20,0 | 1,350000000000000 | 0,181000000000000 | 0,693119631000000 | 18,015028670000000 | 0.773255215 | 24,529701370000000 | 0.128038349 | 9.254499244 | 00747 |
| Vecchiano | 1188 | CPTm | 20,0 | 1,350000000000000 | 0,181000000000000 | 1,725549637000000 | 26,624093190000000 | 1.222836762 | 33,172810870000000 | 1.235680251 | 12.45658378 | 00746 |
| Vecchiano | 1189 | CPTm | 20,0 | 1,350000000000000 | 0,181000000000000 | 2,652355264000000 | 32,120660670000000 | 3.077653684 | 38,379737540000000 | 2.072483607 | 14.56243933 | 00749 |
| Vecchiano | 1190 | CPTm | 20,0 | 1,350000000000000 | 0,181000000000000 | 0,900520907000000 | 23,789127780000000 | 1.340517025 | 29,744976020000000 | 0.487180163 | 11.1547415 | 00748 |
| Vecchiano | 1234 | CPTm | 8,0 | 2,260000000000000 | 0,181000000000000 | 0,000000000000000 | 0,000000000000000 | 0 | 0,000000000000000 | 0 | 0 | 00421 |
| Vecchiano | 1235 | CPTm | 5,0 | 2,260000000000000 | 0,181000000000000 | 0,071161692000000 | 1,811245685000000 | 0.114635201 | 2,037720633000000 | 0 | 0.061720777 | 01162 |
| Vecchiano | 1236 | CPTm | 5,0 | 2,500000000000000 | 0,181000000000000 | 0,055921466000000 | 0,885020355000000 | 0.680563714 | 1,257880384000000 | 0.024534565 | 0 | 28000599_CPT_7234 |
| Vecchiano | 1237 | CPTm | 14,0 | 1,400000000000000 | 0,181000000000000 | 1,127325035000000 | 23,444155790000000 | 1.621701743 | 30,939683920000000 | 0.88192027 | 11.42018794 | 00248 |
| Vecchiano | 1238 | CPTm | 5,0 | 2,500000000000000 | 0,181000000000000 | 0,499002961000000 | 1,605337167000000 | 0.734199575 | 1,545878008000000 | 0 | 0 | 00703 |
| Vecchiano | 1239 | CPTm | 10,0 | 2,500000000000000 | 0,181000000000000 | 0,008005502000000 | 12,735316700000000 | 0.590238494 | 16,872318070000000 | 0 | 2.240907021 | 28000599_CPT_7232 |
| Vecchiano | 1240 | CPTm | 5,0 | 2,500000000000000 | 0,181000000000000 | 0,014527311000000 | 1,388440029000000 | 0.847647604 | 1,965625918000000 | 0 | 0.043107605 | 28000599_CPT_7233 |
| Vecchiano | 1241 | CPTm | 5,0 | 2,560000000000000 | 0,181000000000000 | 0,402978777000000 | 1,346772844000000 | 0.381031773 | 1,556539326000000 | 0 | 0 | 00702 |
| Vecchiano | 1242 | CPTm | 5,0 | 2,590000000000000 | 0,181000000000000 | 0,470922216000000 | 1,522353931000000 | 0.534619561 | 1,981954600000000 | 0 | 0 | 00701 |
| Vecchiano | 1243 | CPTm | 5,0 | 2,590000000000000 | 0,181000000000000 | 0,000000000000000 | 1,874663010000000 | 1.03507204 | 2,151952527000000 | 0 | 0.016604065 | 28000599_CPT_7231 |

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# LIQUEFACTION DATABASE


WEBSITE

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**http://www.regione.toscana.it/speciali/rischio-sismico**

**sismica@regione.toscana.it**