



liquefact

This research has been carried out within the framework of the European LIQUEFACT project. The LIQUEFACT project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 700748



IL PROGETTO LIQUEFACT IN EMILIA-ROMAGNA - webinar, 17/02/2021

9:30 – 9:50 Saluti e introduzione

9:50 - 10:05 **Il progetto europeo LIQUEFACT** - *Lai C.G.*

10:05 - 10:20 **Il supporto a LIQUEFACT della Regione Emilia-Romagna e delle Amministrazioni Locali** - *Martelli L.*

10:20 - 10:40 **Zonazione multi-scala del rischio di liquefazione sismo-indotta. Microzonazione del Comune di Cavezzo (Modena)** - *Lai C.G., Meisina C., Bozzoni F.*

10:40 - 11:00 **Valutazione della vulnerabilità di strutture ed infrastrutture alla liquefazione sismo-indotta dei terreni. Sviluppo di modelli di fragilità empirici per edifici in muratura utilizzando i dati della Regione Emilia-Romagna.** - *Di Ludovico M., Chiaradonna A., Bilotta E., Flora A., Prota A.*

11:00 - 11:20 **Analisi del rischio liquefazione sismo-indotta a scala urbana: applicazione al Comune di Terre del Reno.** *Modoni G., Spacagna R.L., Paoletta L., D'Apuzzo M., Evangelisti A.*

11:20 - 11:40 **Tecniche di mitigazione del rischio liquefazione sismo-indotta dei terreni.** *Flora A., Bilotta E., Chiaradonna A., Fasano G., Lirer S., Mele L., Nappa V.*

11:40 - 12:00 **Modellazione fisica in centrifuga delle tecniche di mitigazione del rischio liquefazione sismo-indotta** *Fioravante V., Giretti D., Airoldi S., Moglie J.*

12:00 - 12:20 **Valutazione dell'efficacia delle tecniche di mitigazione: il campo prova di Pieve di Cento** *Pingue L., Siepi M.*

12:20 - 12:40 **LIQUEFACT software, a tool for liquefaction risk assessment, mitigation planning, and decision support** *Meslem A., Iversen H.*

12:40 – 13:00 Discussione e chiusura lavori

Analisi del rischio liquefazione sismo-indotta a scala urbana:
applicazione al Comune di Terre del Reno

Bologna, 17 febbraio 2021

IL PROGETTO LIQUEFACT IN EMILIA-ROMAGNA

Webinar
Mercoledì 17 febbraio 2021

Assessment and mitigation of liquefaction potential across Europe: a holistic approach to protect structures/infrastructures for improved resilience to earthquake-induced liquefaction disasters

ANALISI DEL RISCHIO LIQUEFAZIONE SISMO-INDOTTA A SCALA URBANA: APPLICAZIONE AL COMUNE DI TERRE DEL RENO

Giuseppe Modoni, Anna Baris, Mauro D'Apuzzo, Azzurra Evangelisti,
Luca Paoella, Rose Line Spacagna



Esposizione

E

x

Vulnerabilita'

V

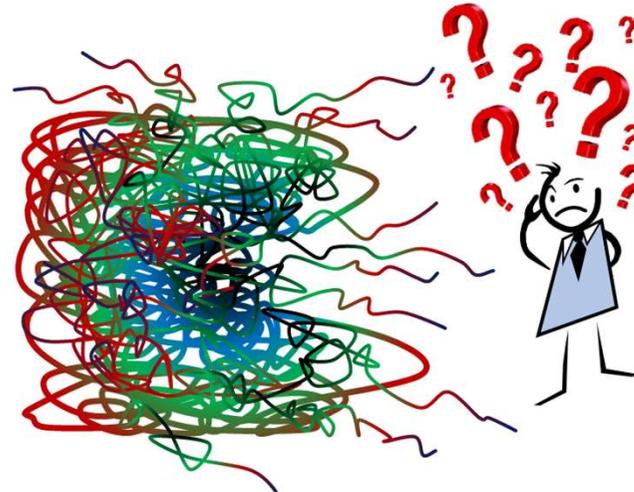
x

Pericolosità

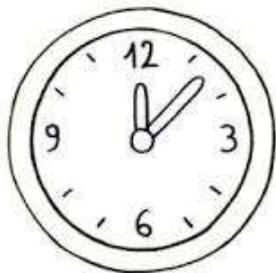
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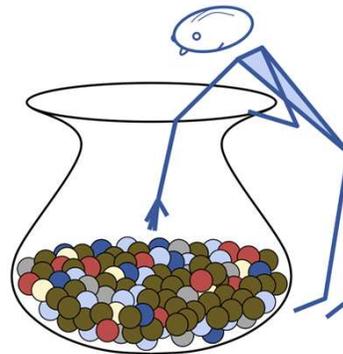
UNCERTAINTY



TIME

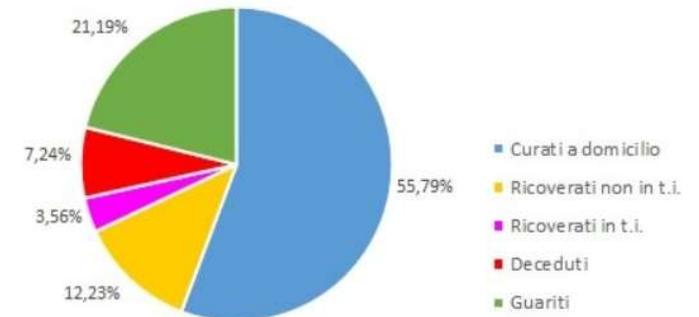


HAZARD OCCURRENCE



LIKELIHOOD OF DAMAGE

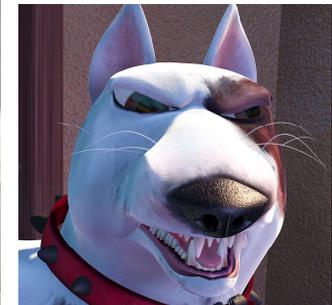
Distribuzione dei contagiati totali (%)





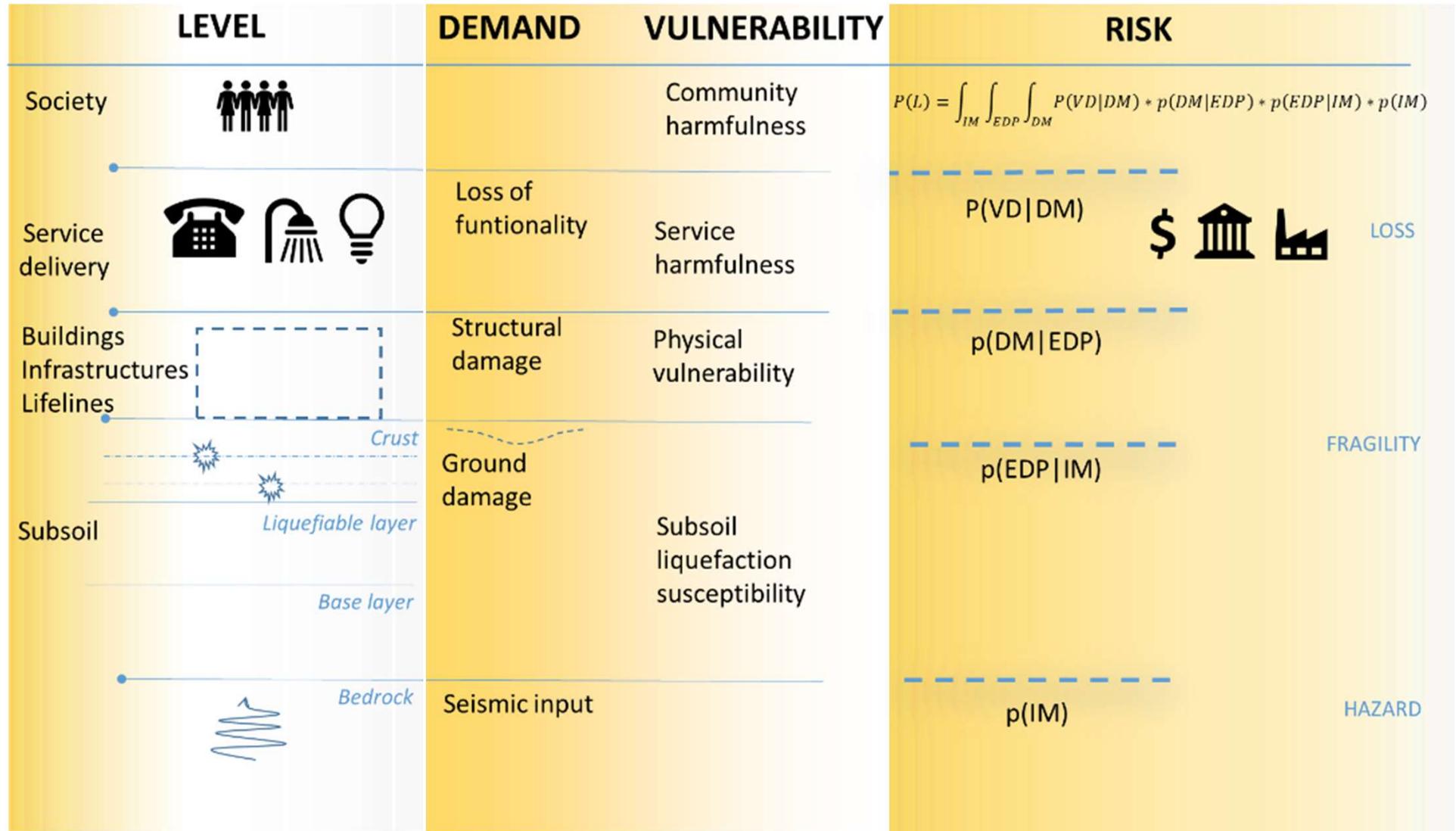
PROBABILISTIC RISK

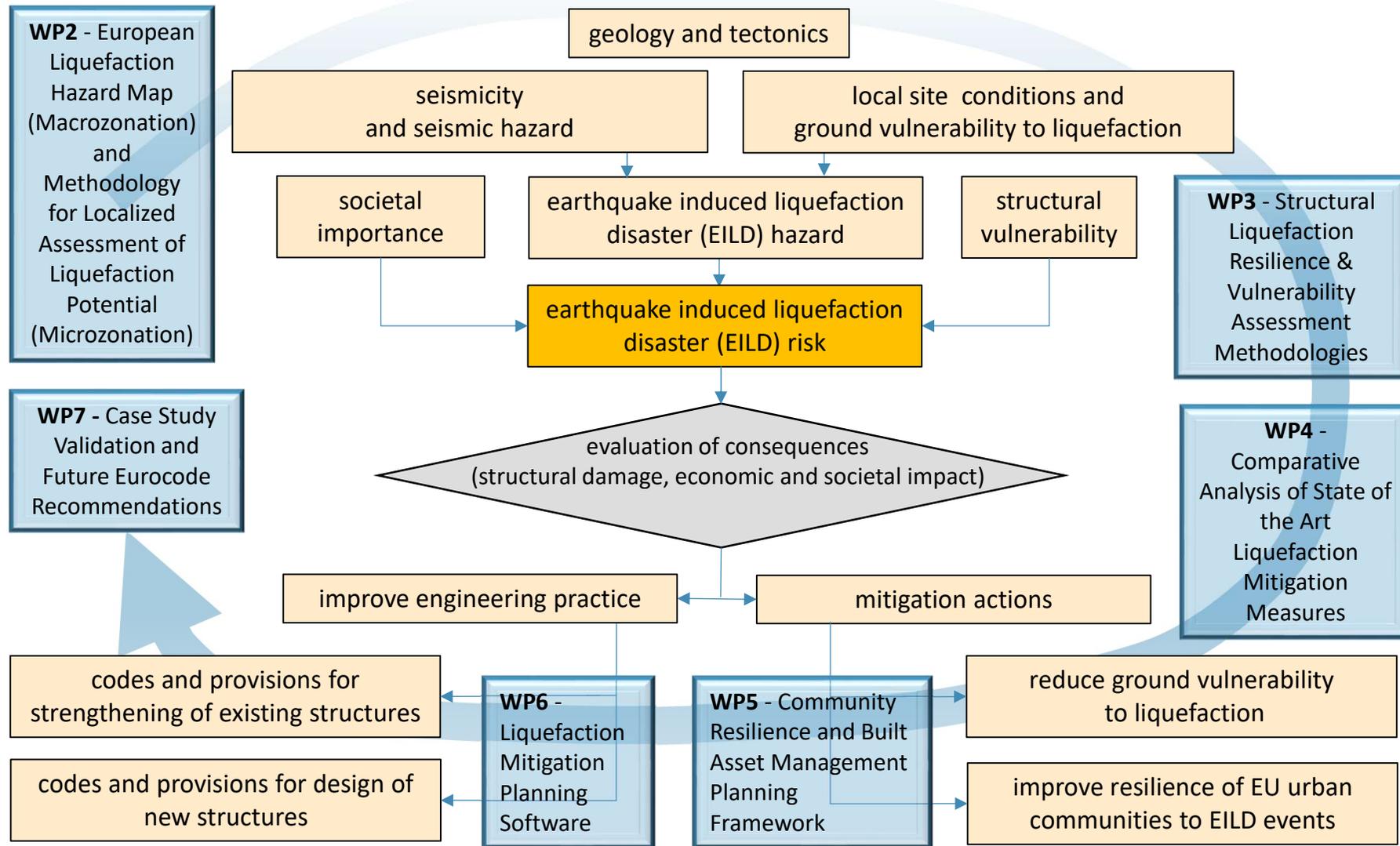
$$p(IM)$$

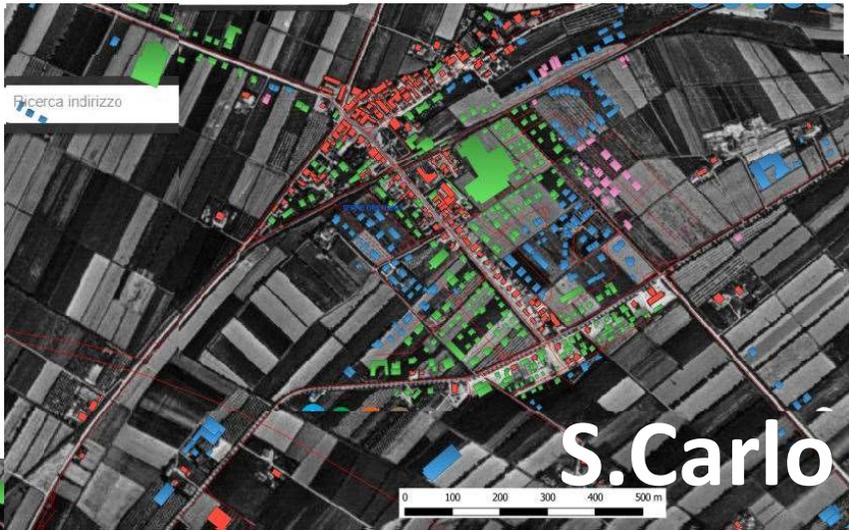


PEER - Cornell & Krawinkler (2000)

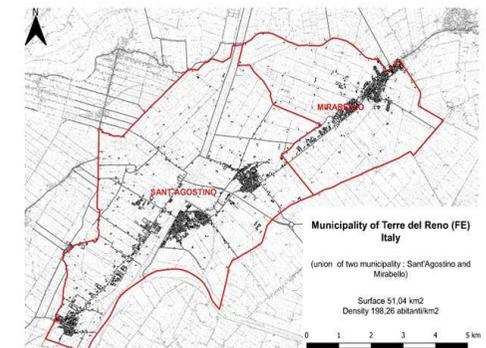
HOLISTIC LIQUEFACTION RISK: A CASCADE ANALYSIS







Aerial Imagery 1954



1954

1976

1994

2003

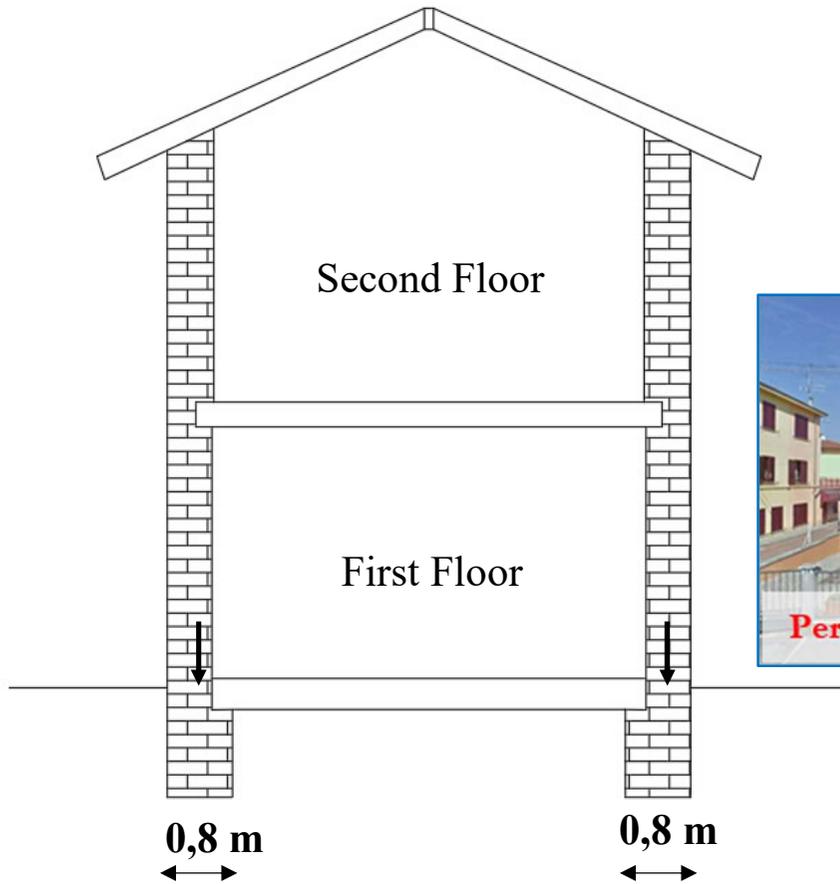
2008

Year

Analisi del rischio liquefazione sismo-indotta a scala urbana:
applicazione al Comune di Terre del Reno

Bologna, 17 febbraio 2021

TERRE DEL RENO (ITA) May 20th 2012 $M_w=6.1$



SAMPLE BUILDING IN THE MUNICIPALITY OF TERRE DEL RENO

Modello Unico Digitale per l'Edilizia MUDE

TERRE DEL RENO (ITA) May 20th 2012 $M_w=6.1$

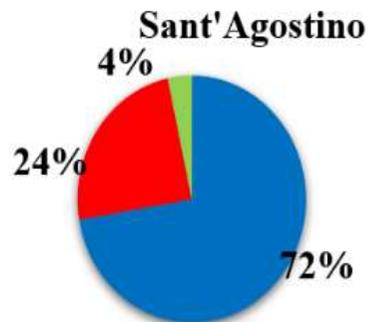
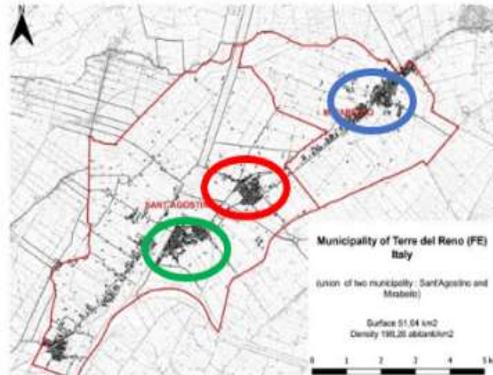
Dwelling Foundation Damage Categories			
Type of Damage	Minor	Moderate	Major
Stretching 	0 to 5mm	5 to 30mm	>30mm
Hogging 	0 to 20mm	20 to 50mm	>50mm
Dishing 	0 to 20mm	20 to 50mm	>50mm
Racking/Twisting 	0 to 10mm	10 to 30mm	>30mm
Tilting 	0 to 20mm	20 to 50mm	>50mm
Abrupt Differential Movement 	0 to 10mm	10 to 20mm	>20mm
Global Settlement 	0 to 50mm	50 to 100mm	>100mm

VAN BALLEGOOY (2014)

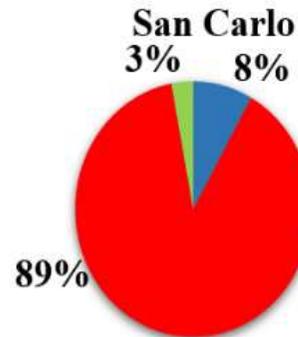


Modello Unico Digitale per l'Edilizia MUDE

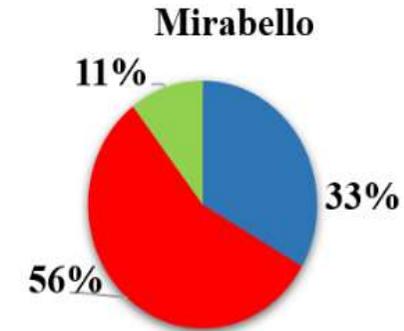
TERRE DEL RENO (ITA) May 20th 2012 $M_w=6.1$



Type of damage	Euro	%
Total	43000000	100
shaking	31000000	72%
liquefaction	10500000	24%
combined	1450000	3%



Type of damage	Euro	%
Total	35000000	100%
shaking	2900000	8%
liquefaction	31000000	89%
combined	1100000	3%



Type of damage	Euro	%
Total	36500000	100%
shaking	12000000	33%
liquefaction	20500000	56%
combined	3800000	10%



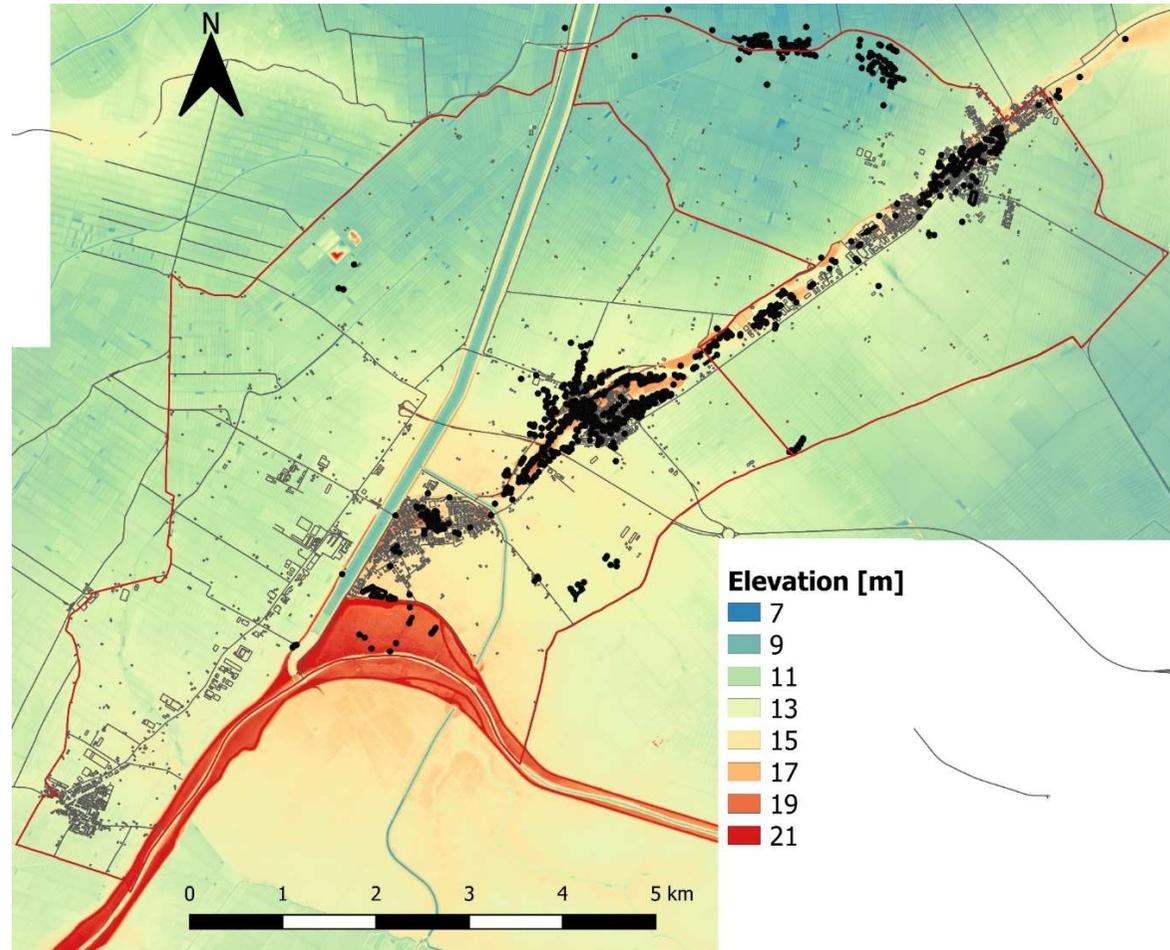
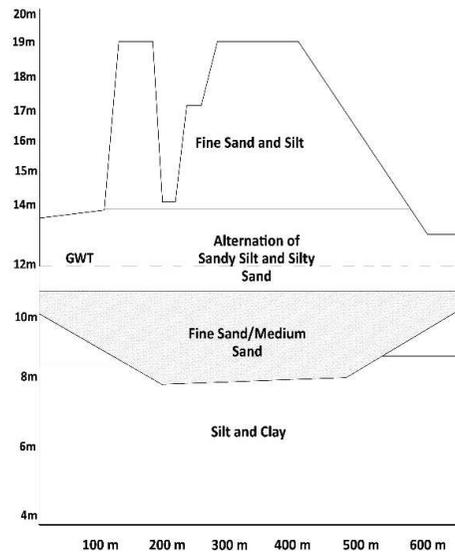
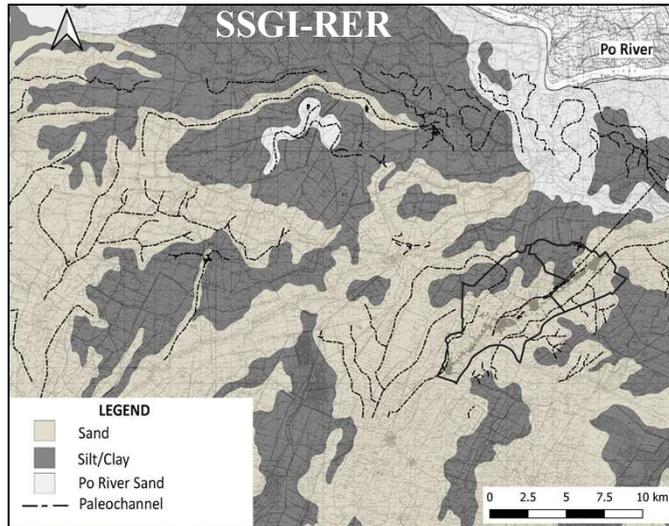
OPEN RICOSTRUZIONE

Monitora gli interventi per la ricostruzione in Emilia-Romagna

<https://openricostruzione.regione.emilia-romagna.it/>

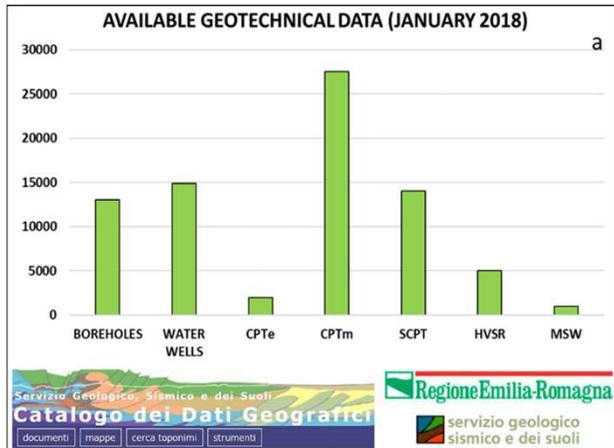
Update: November 30, 2018

TERRE DEL RENO (ITA) May 20th 2012 $M_w=6.1$

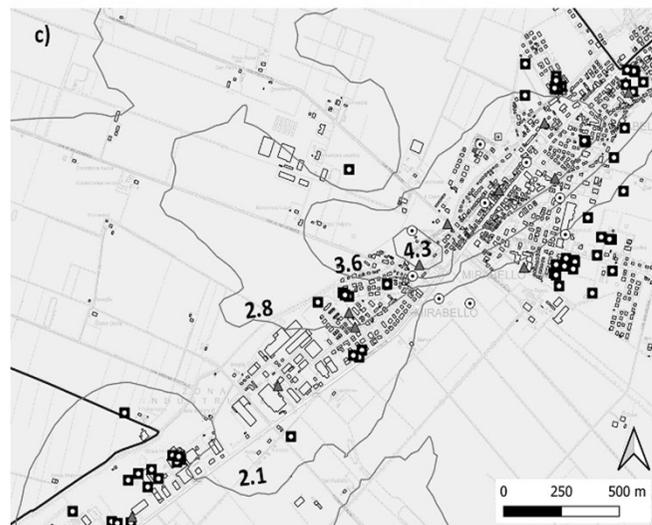
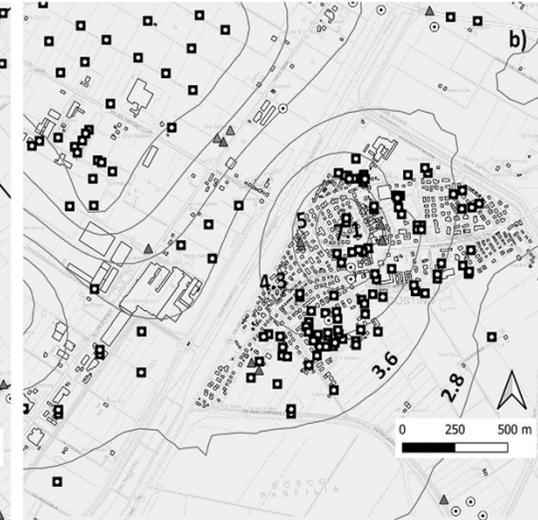
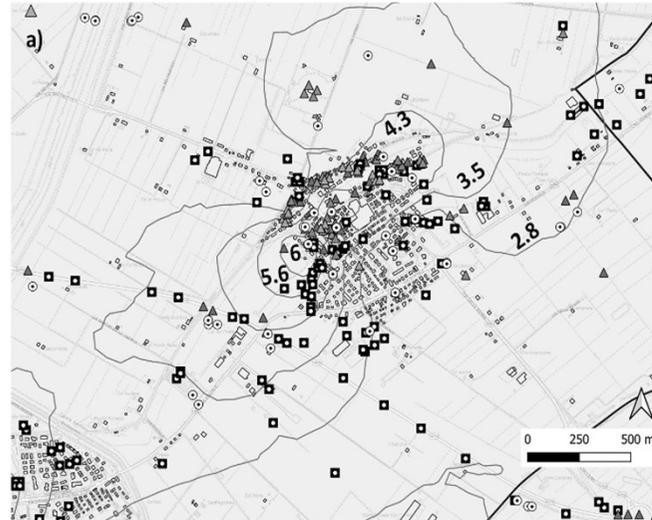


1457 - 1767/95

TERRE DEL RENO (ITA) May 20th 2012 $M_w=6.1$



≈85000 investigation

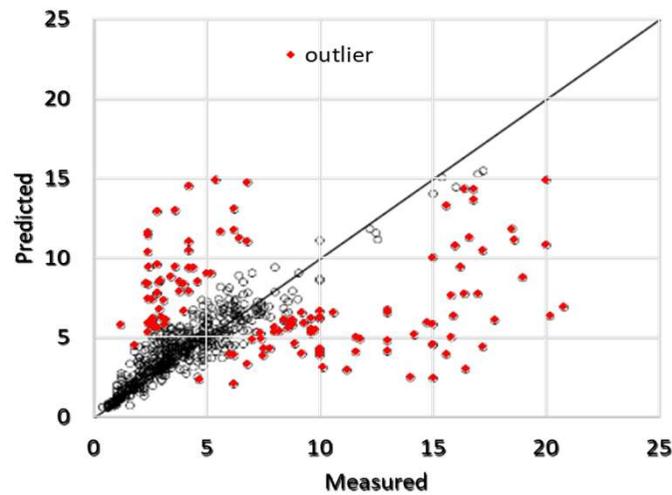
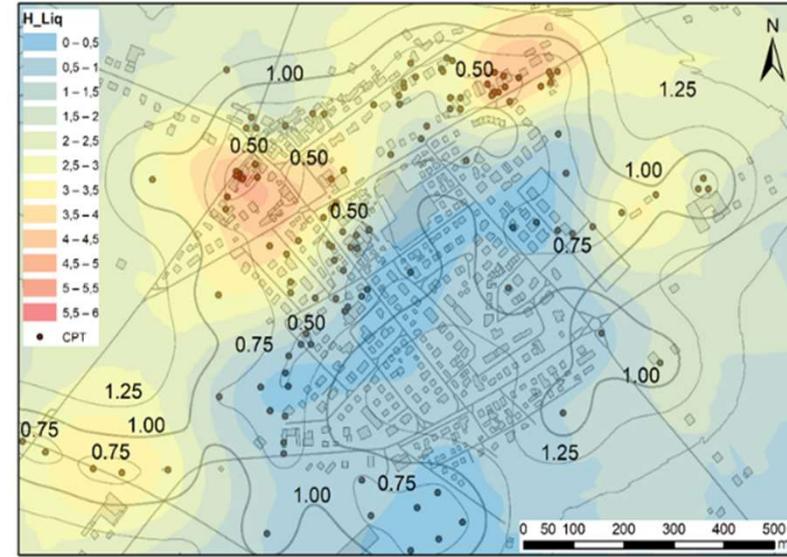
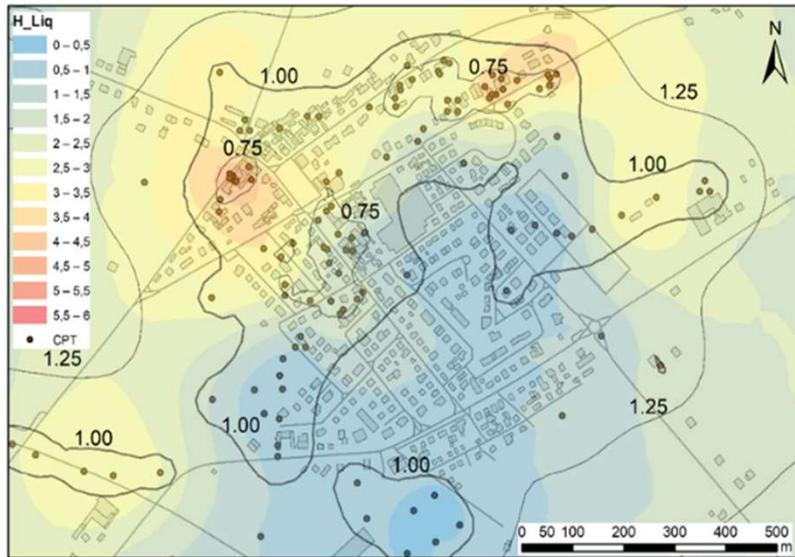


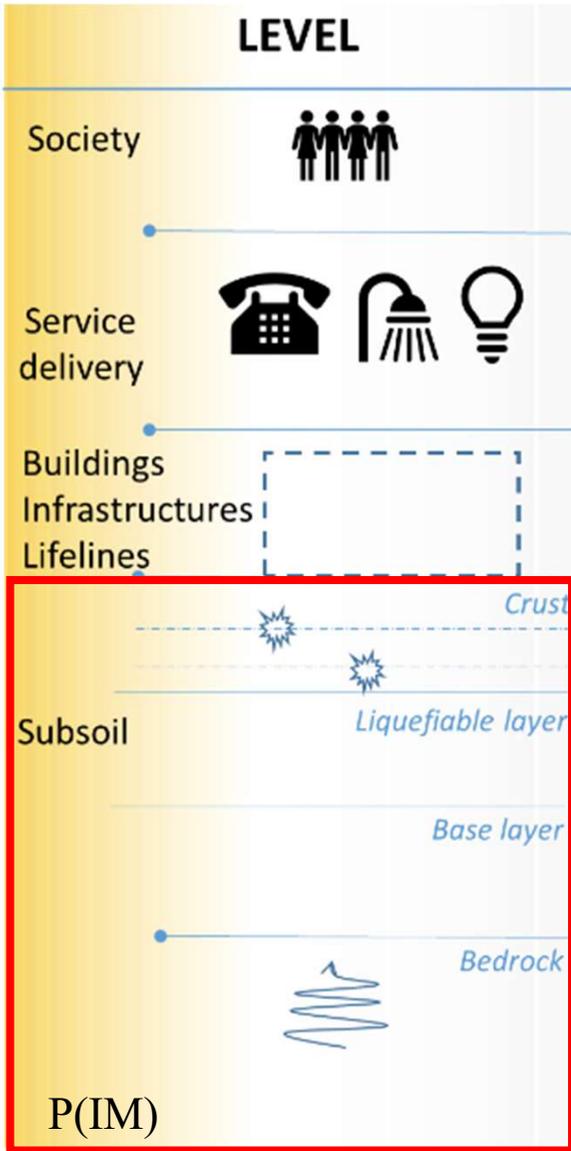
LEGEND

- CPTm
- ▲ CPTe/CPTu
- Borehole
- Groundwater depth

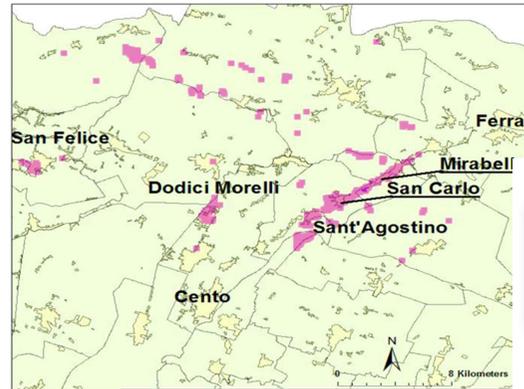
≈200 boreholes logs
 ≈ 800 CPTm or CPTe

TERRE DEL RENO (ITA) May 20th 2012 $M_w=6.1$

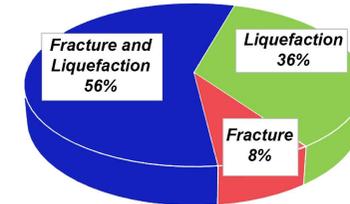




LAND DAMAGE CLASSIFICATION



EMERGEO (INGV, 2012)



Sand boil



Fracture

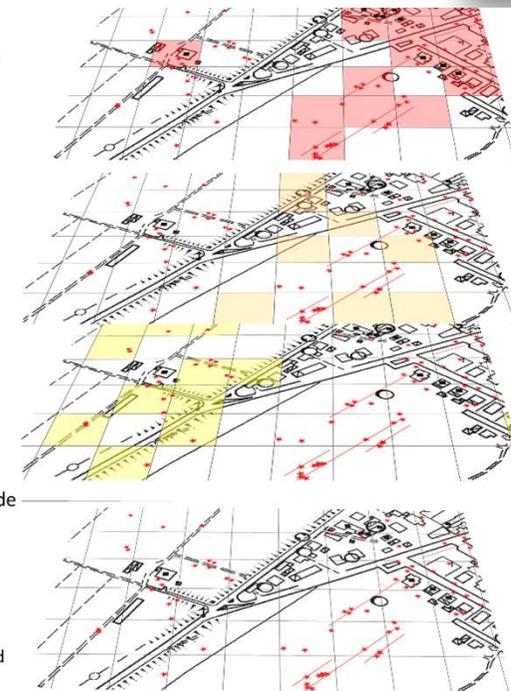


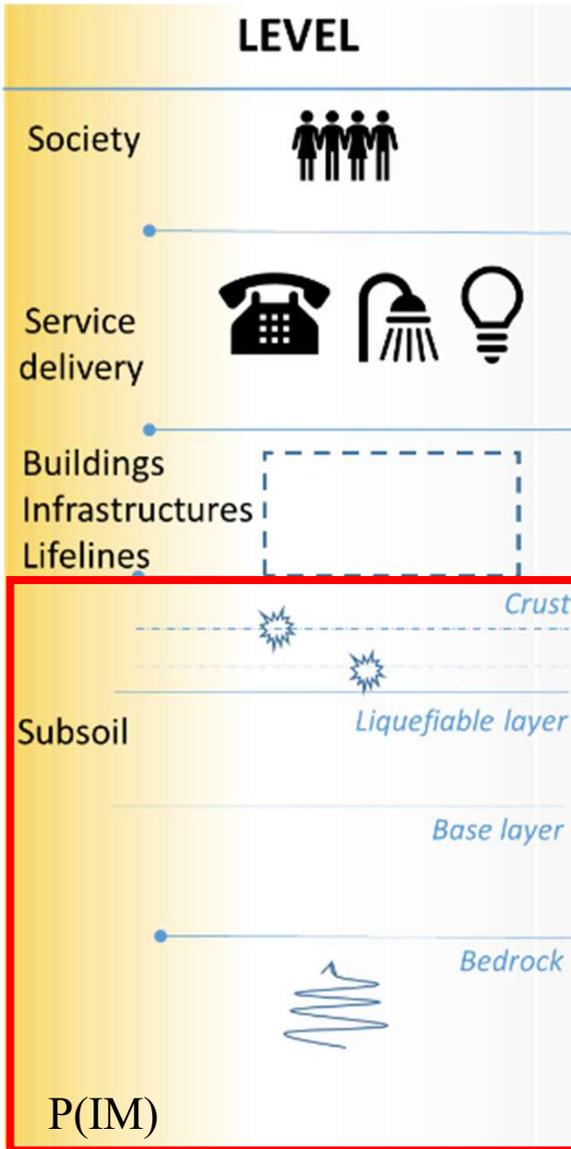
Damage Level 3: building damage, major cracks

Damage Level 2: sand boils + minor crack

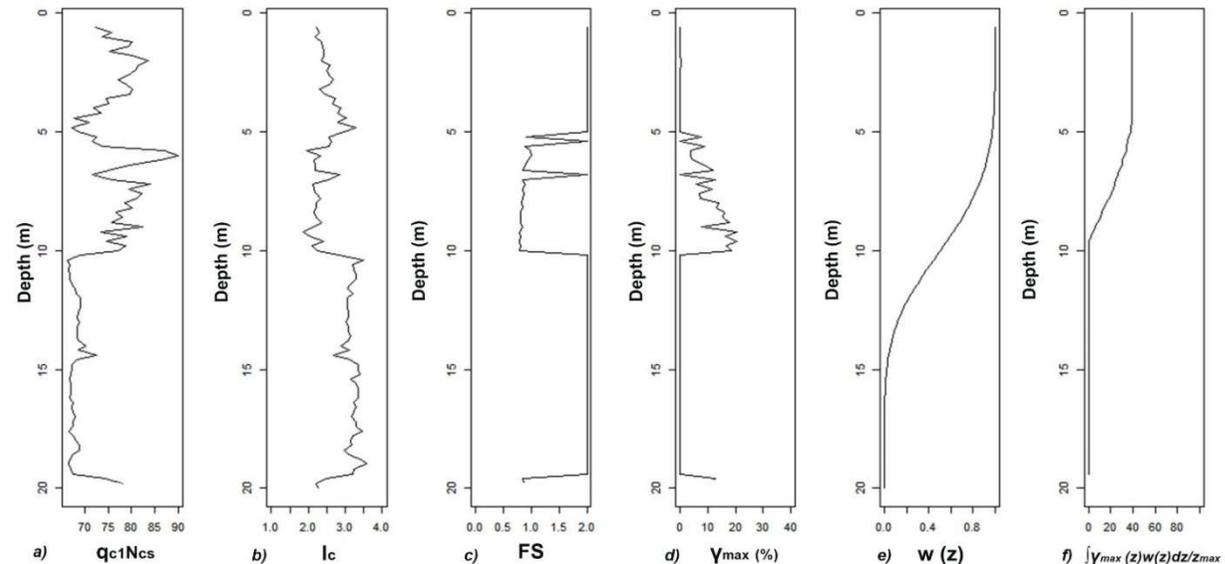
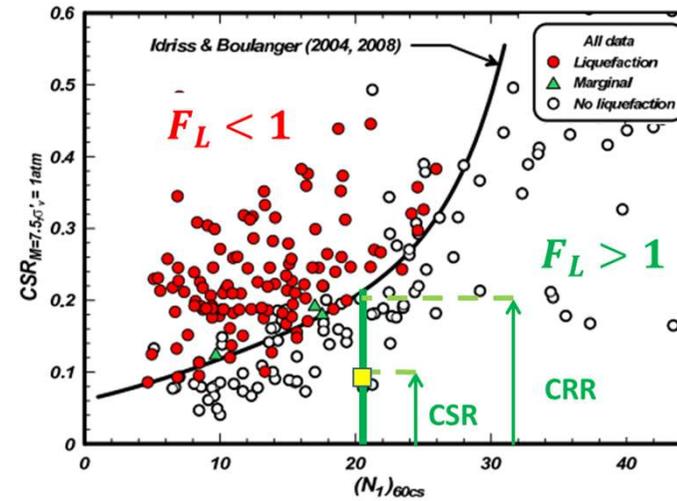
Damage Level 1: at least 1 sand boil is found inside the cell.

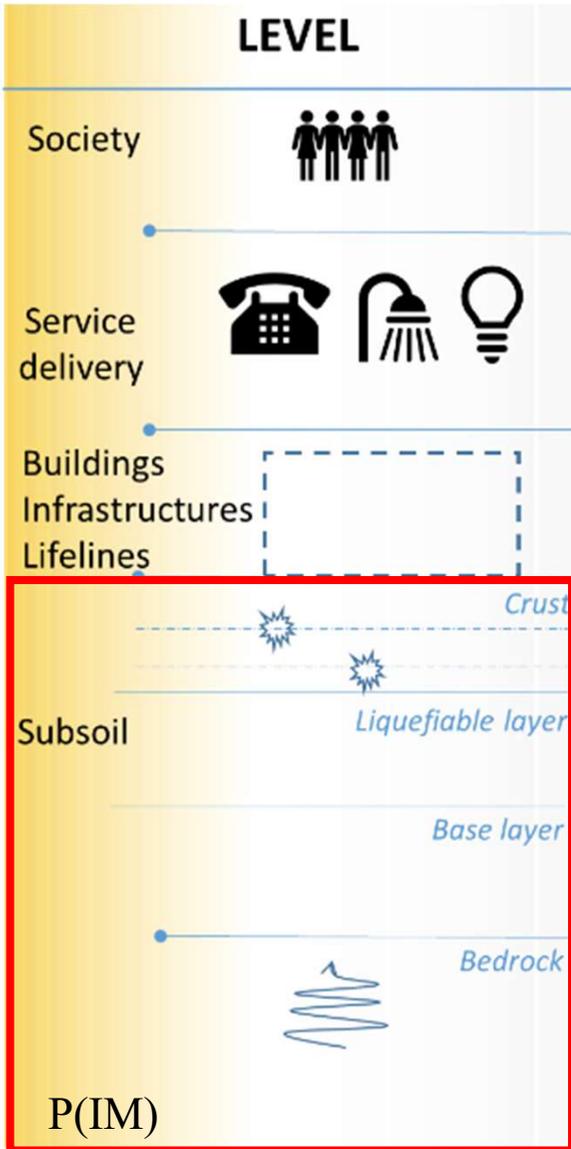
Overlapping of a 50x50 m grid to the liquefaction-induced damage observations.





LAND DAMAGE PREDICTION



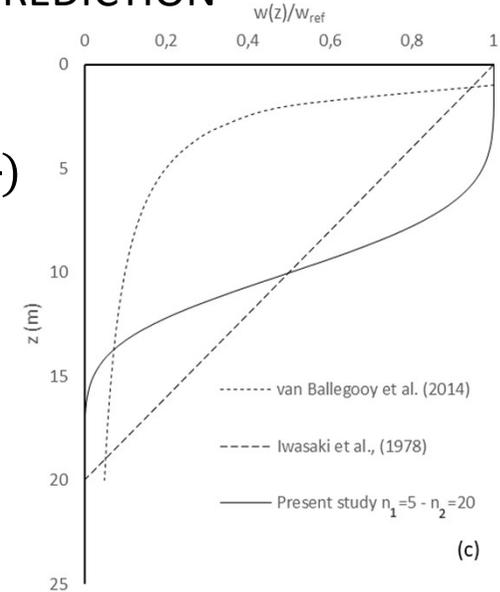


LAND DAMAGE PREDICTION

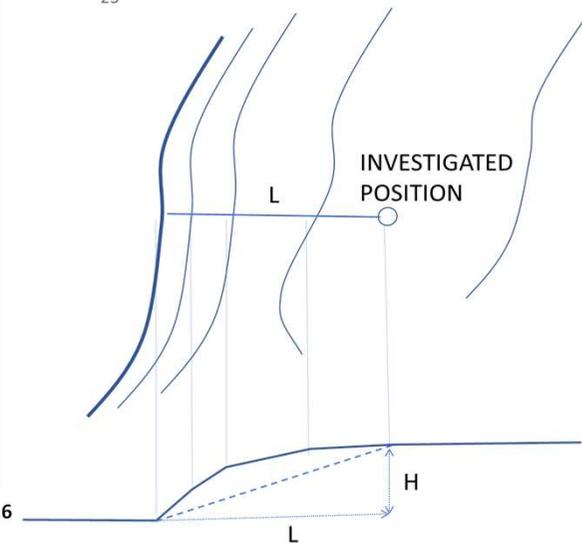
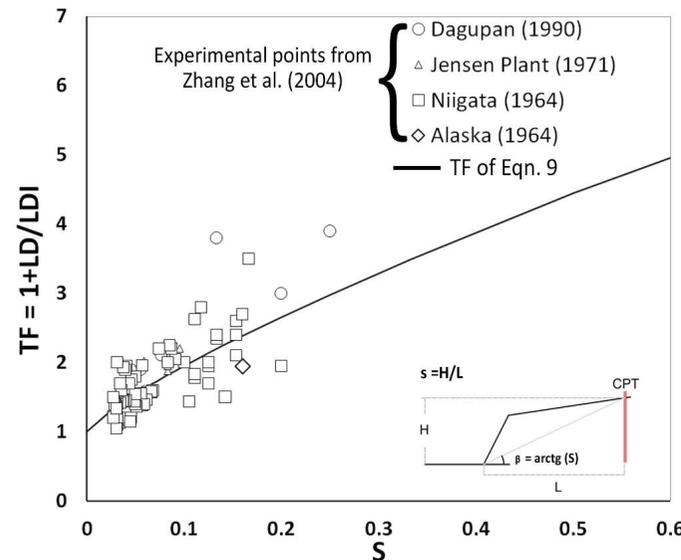
Stratigraphic effect

$$GLSN = TF \int_0^1 \gamma_{max} * w\left(\frac{z}{z_{max}}\right) d\left(\frac{z}{z_{max}}\right)$$

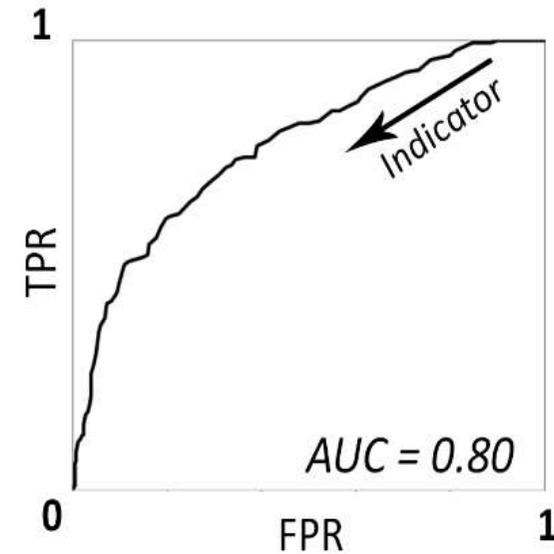
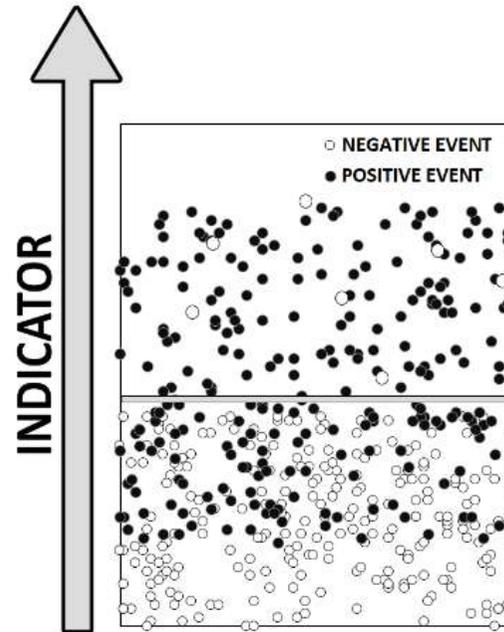
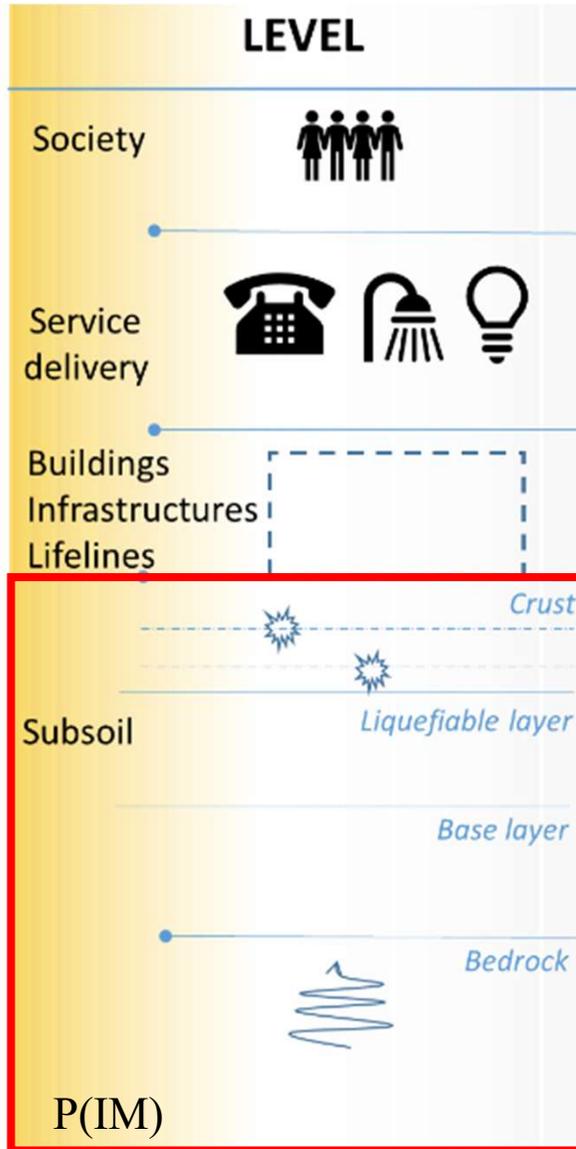
$$w\left(\frac{z}{z_{max}}\right) = 10 \cdot \left(1 - \frac{\pi}{2} \cdot \left(\arctan\left(\frac{z}{z_{max}}\right)\right)^{n_1}\right)^{n_2}$$



Topographic effect



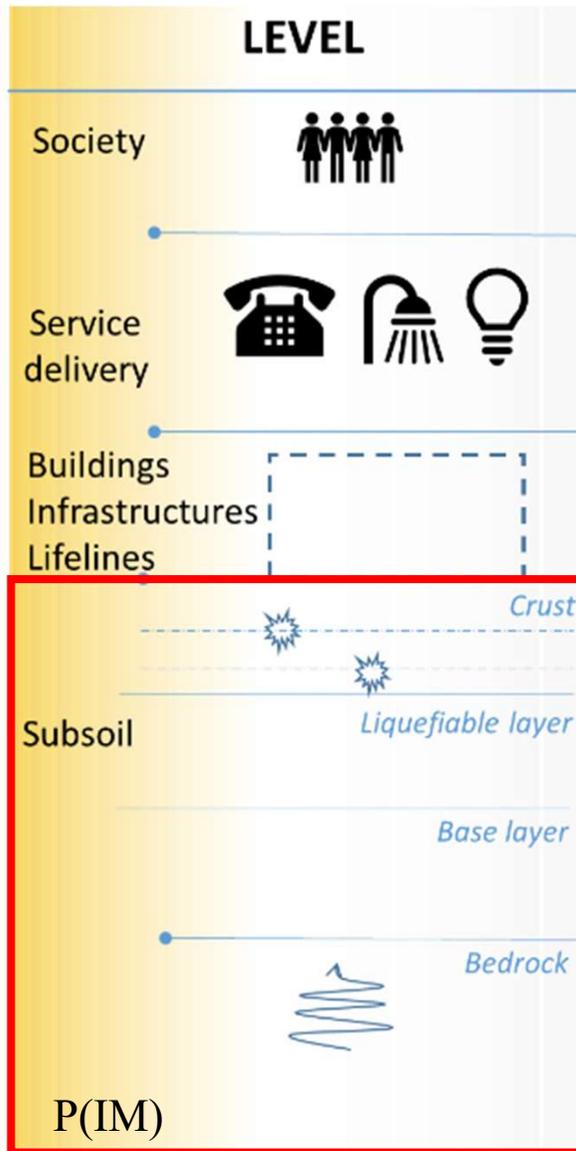
LAND DAMAGE PREDICTION



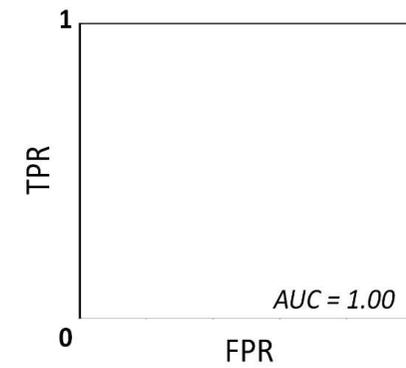
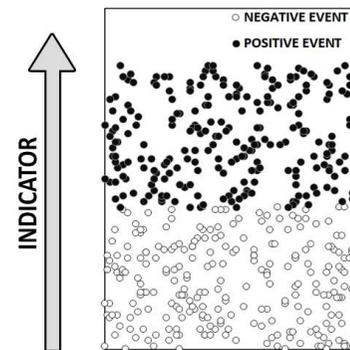
Kongar et al., 2015

$$MCC = \frac{TP \times TN - FP \times FN}{\sqrt{(TP + FP)(TP + TN)(FN + FP)(FN + TN)}}$$

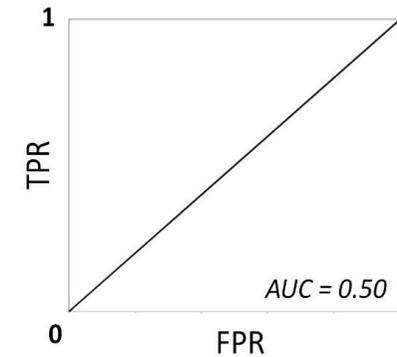
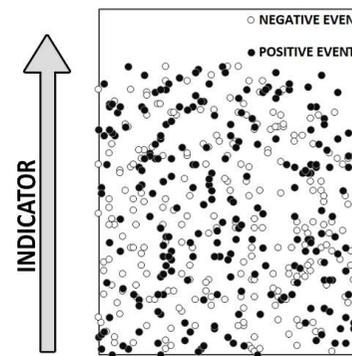
LAND DAMAGE PREDICTION



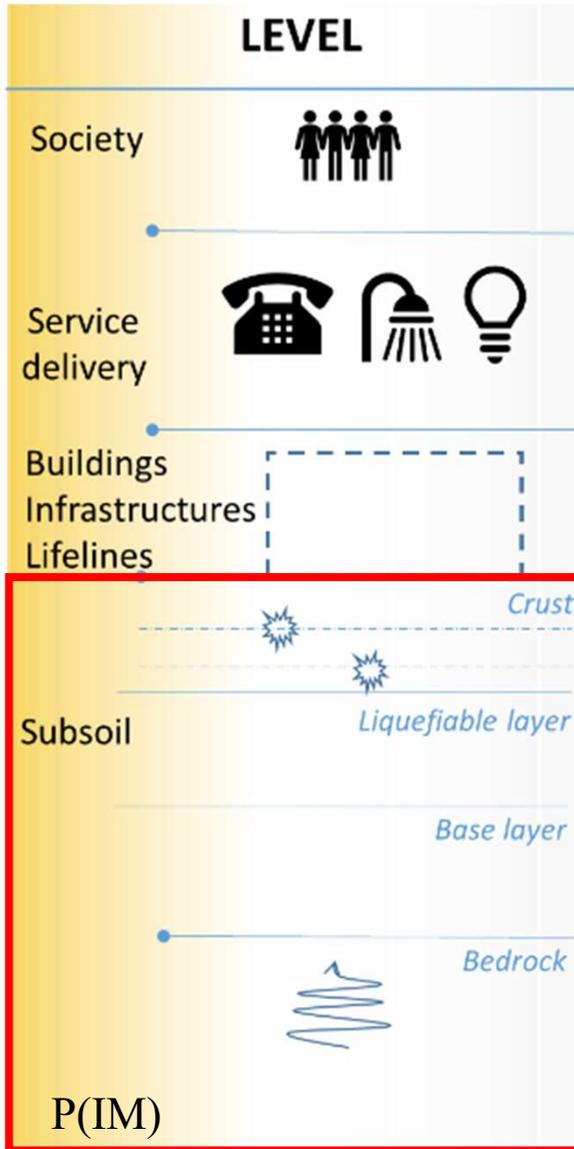
CASE A



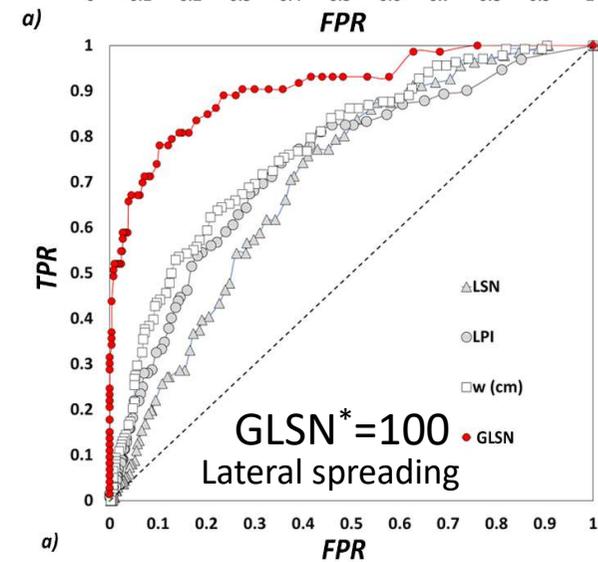
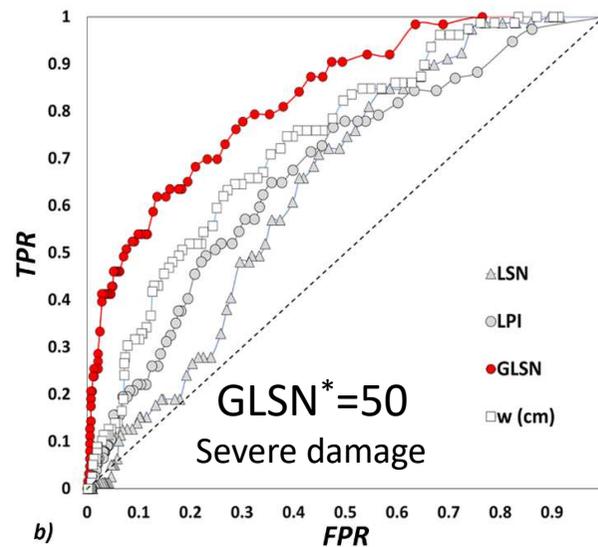
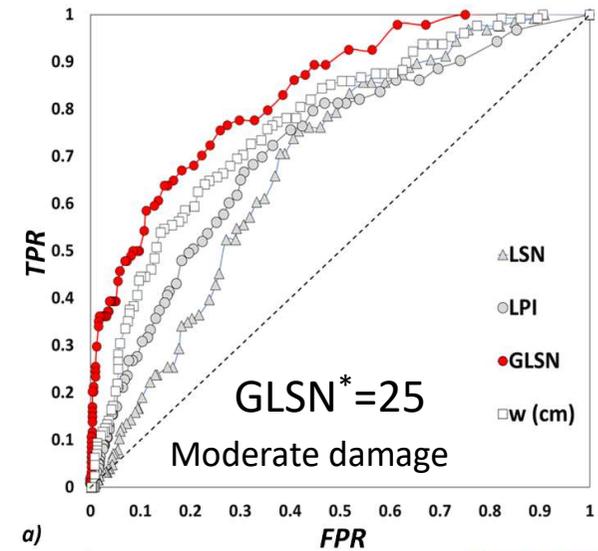
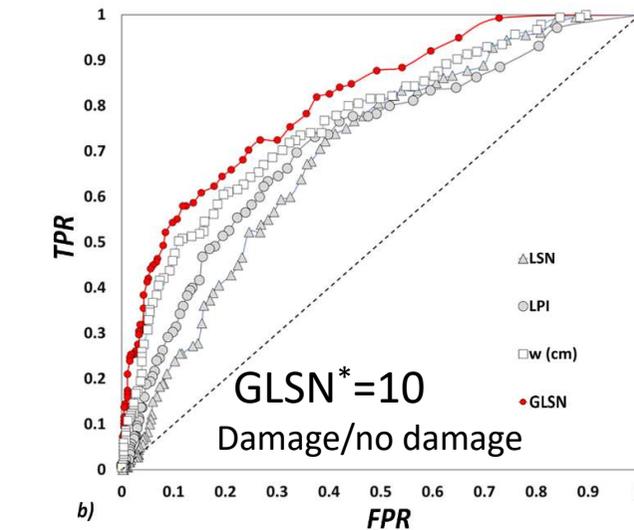
CASE B



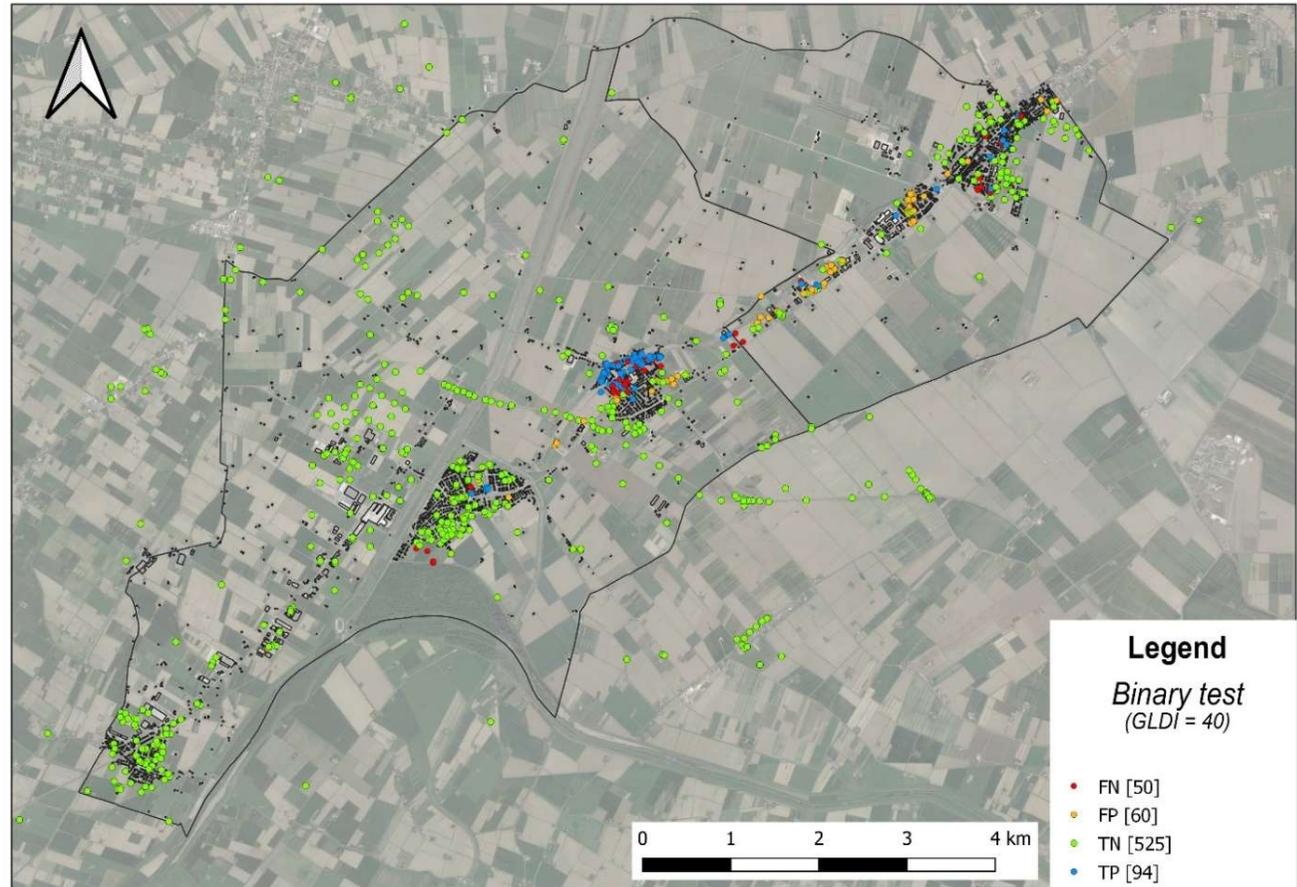
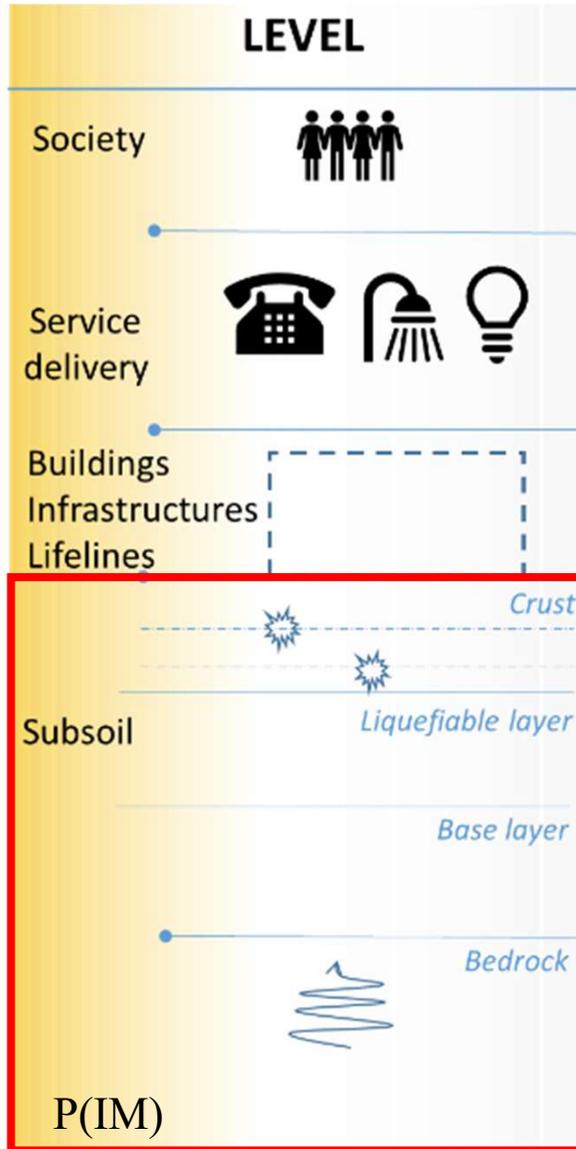
Kongar et al., 2015

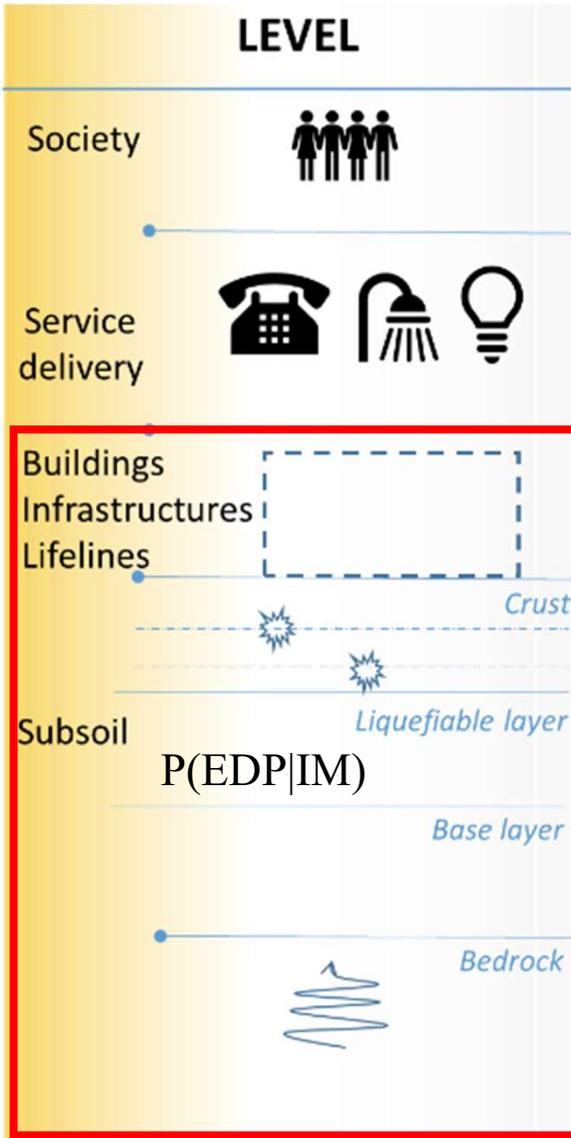


LAND DAMAGE PREDICTION

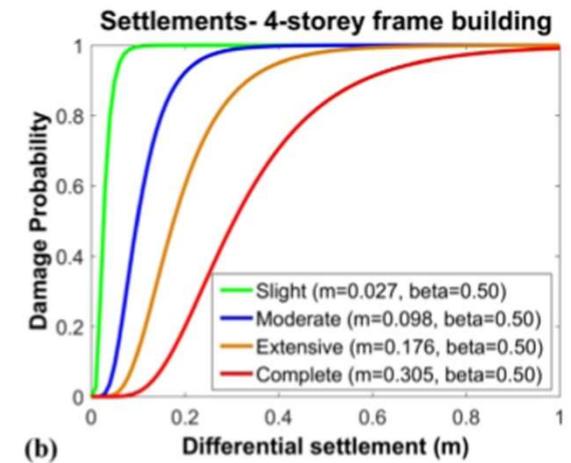
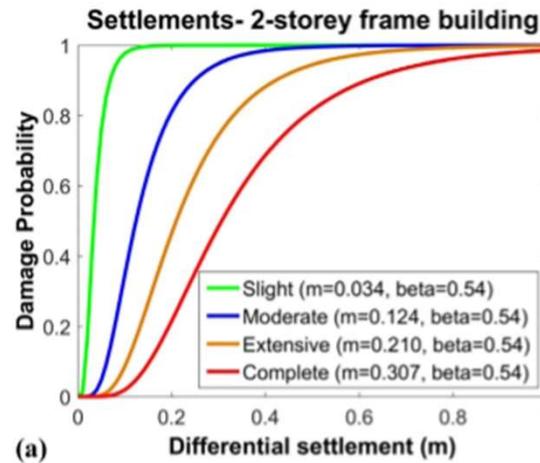
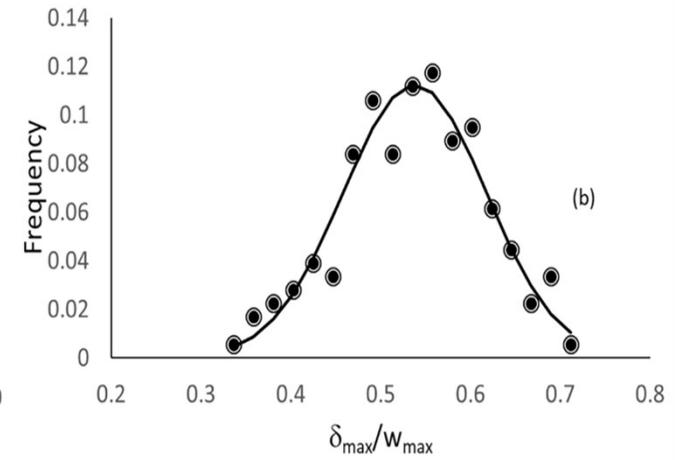
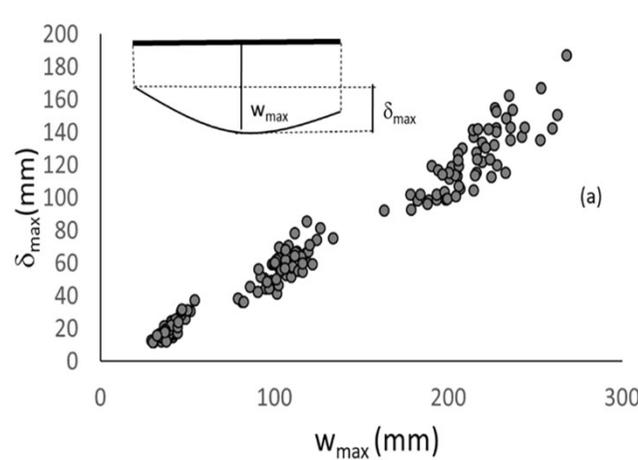


LAND DAMAGE PREDICTION





BUILDING DAMAGE PREDICTION



Fotopoulou et al., (2018)



EXPOSURE

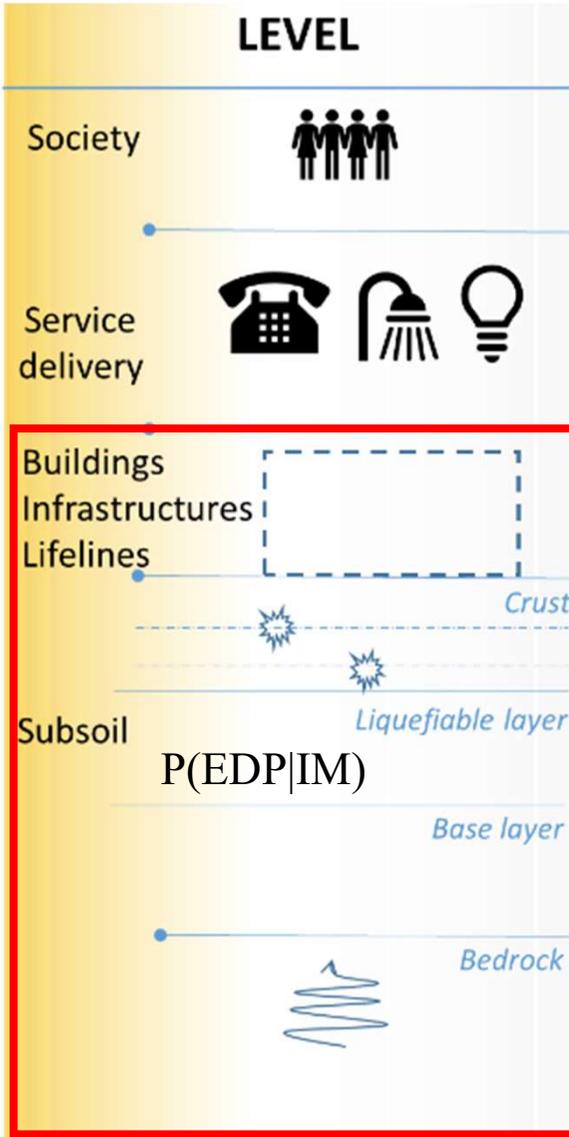
Direct damage



Indirect damage



BUILDING DAMAGE PREDICTION



		Slight	Moderate	Extensive	Complete
Edifici Residenziali	<i>rc/RC</i>	0.02	0.10	0.45	1.00
	<i>INV/PROD</i>	-	-	-	-
	<i>INV damage</i>	-	-	-	-
	<i>BRT (giorni)</i>	5	120	360	720
	<i>SIM</i>	0	0.5	1.0	1.0
Edifici Industriali	<i>rc/RC</i>	0.02	0.10	0.355	1.00
	<i>INV/PROD</i>	0.05	0.05	0.05	0.05
	<i>INV damage</i>	0.0	0.0	0.0	0.50
	<i>BRT (giorni)</i>	10	90	240	360
	<i>SIM</i>	0.5	1.0	1.0	1.0

Hazus
(FEMA, 2003)

PHYSICAL DAMAGE
REPAIR COSTS

$$\begin{aligned}
 \text{tot_rc}_i &= \text{rc}_i + \text{INV_DAM}_i \\
 &= \text{RC}_i \left(\sum_{ds} P_{ids} \cdot [(rc_i/RC_i)_{ds_i}] \right)
 \end{aligned}$$

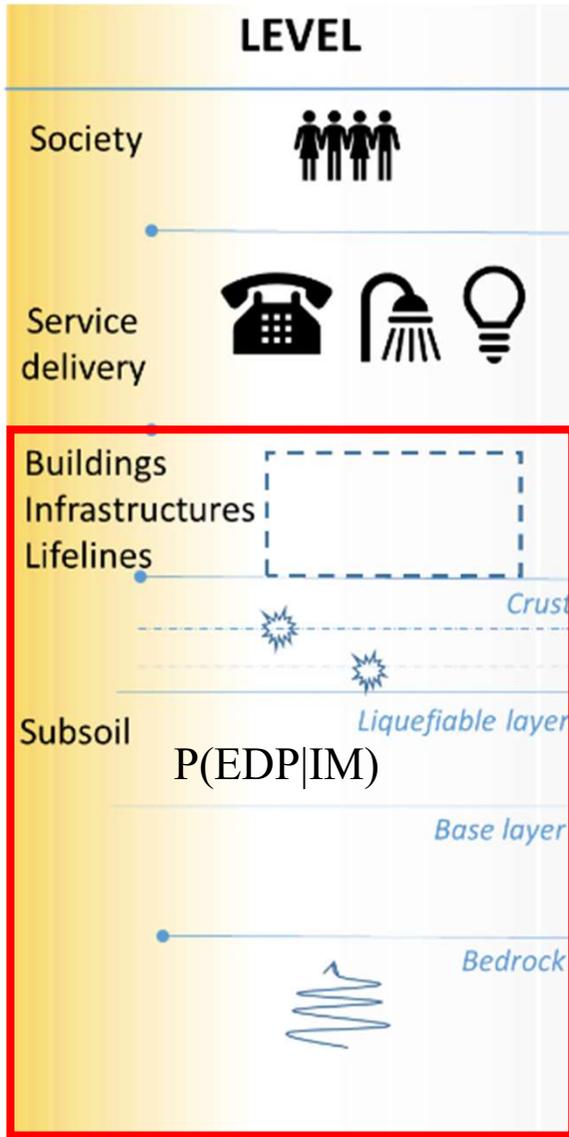
LOSS FACTORS

TOTAL ECONOMIC LOSS
LOSS OF BUSINESS INVENTORY

TEMPORARY RENT/ LOSS OF INCOME

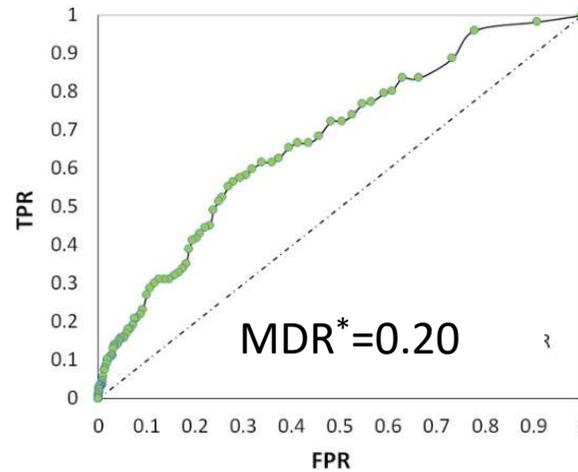
$$ul_i = \sum_{ds} (\text{INC}_i \cdot \text{FLT}_i) \cdot P_{i_ds}$$

RESTORATION TIME $\text{FLT}_i = \text{BRT}_i \cdot \text{SIM}_i$

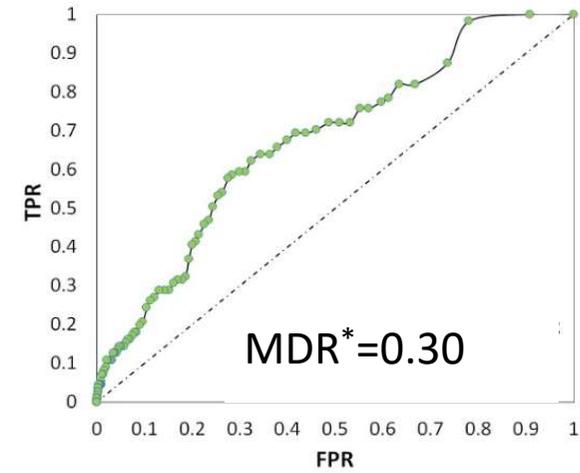


BUILDING DAMAGE PREDICTION

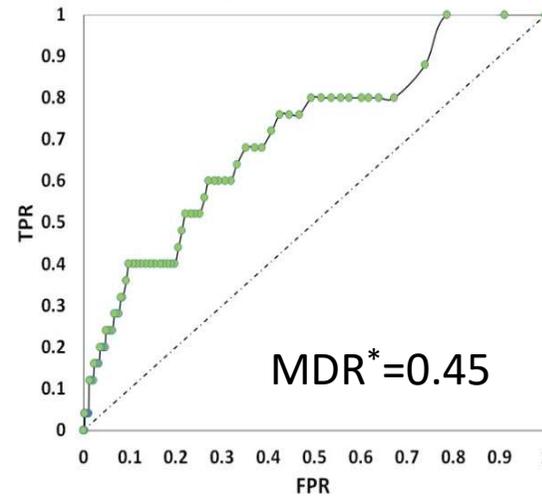
DAMAGE LEVEL 1



DAMAGE LEVEL 2

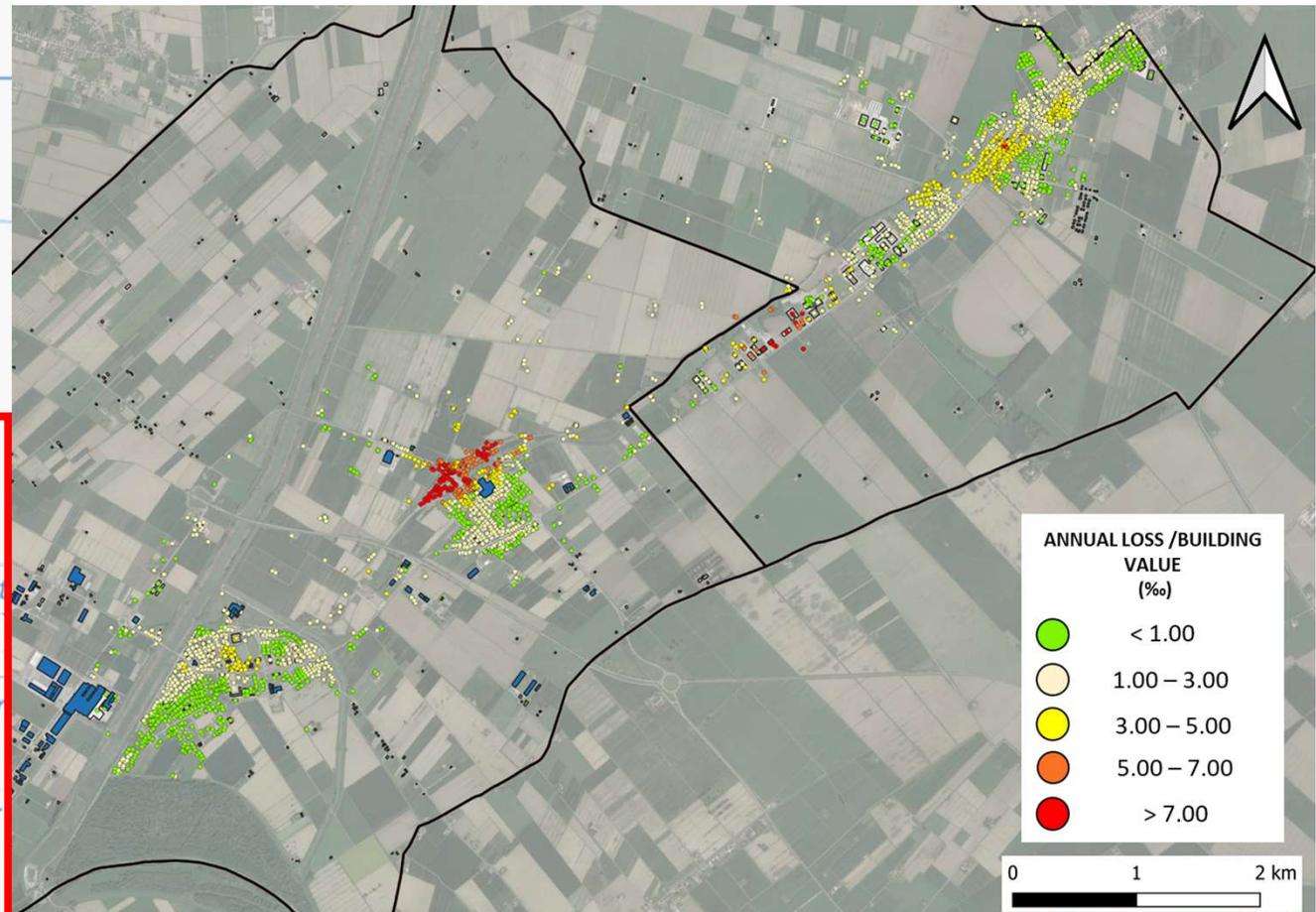
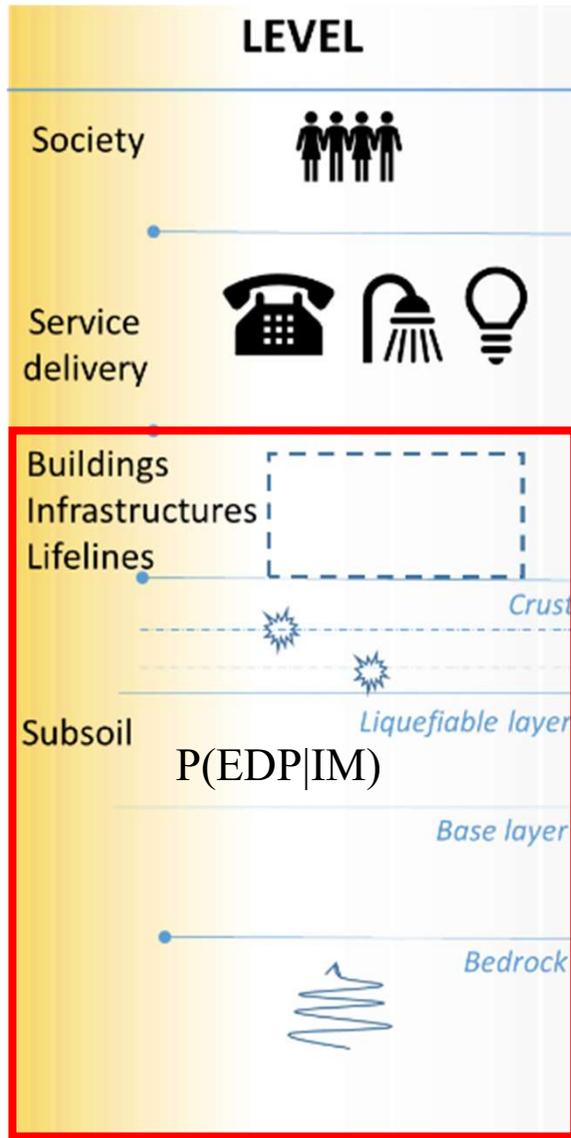


DAMAGE LEVEL 3



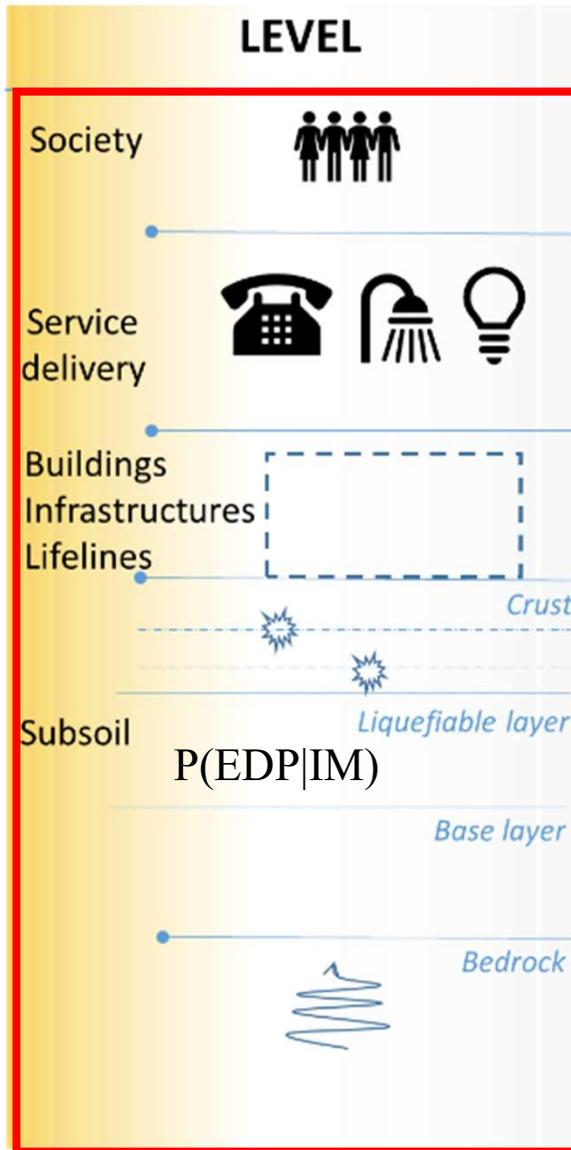
COST/BENEFIT





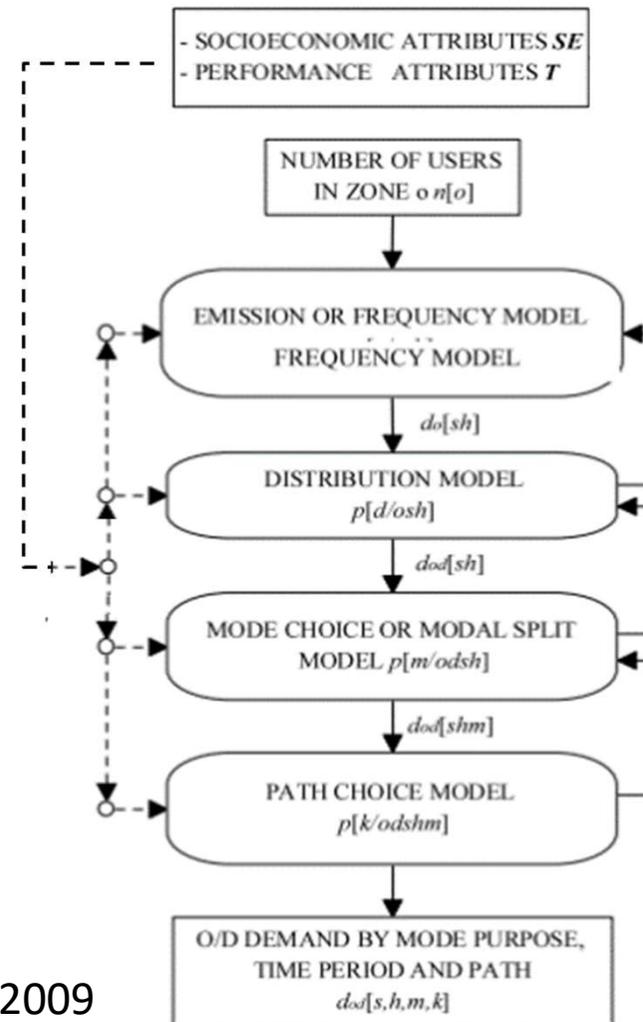
Reconstruction cost "RC" € 2 500.00/m²
Building Value= € 1 000.00/m²
Utility loss cost "ul"= € 6.00/(m²*month)

<https://www.regione.emilia-romagna.it/terremoto/mudemodello-unico-digitale-per-ledilizia>



ROAD SERVICE DELIVERY

*Travel
Demand
Forecast
Model*



Cascetta, 2009

LEVEL

Society



Service delivery



Buildings

Infrastructures

Lifelines



Subsoil

$P(EDP|IM)$

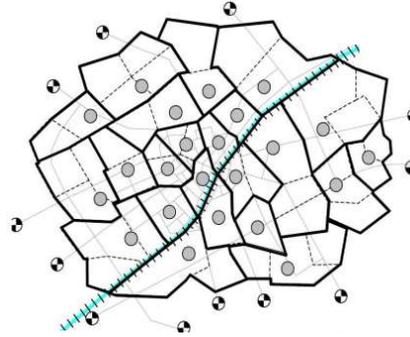
Liquefiable layer

Base layer

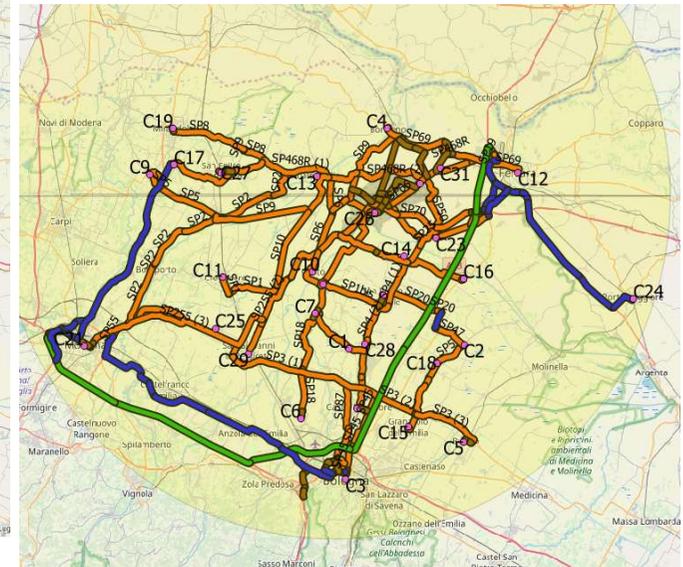
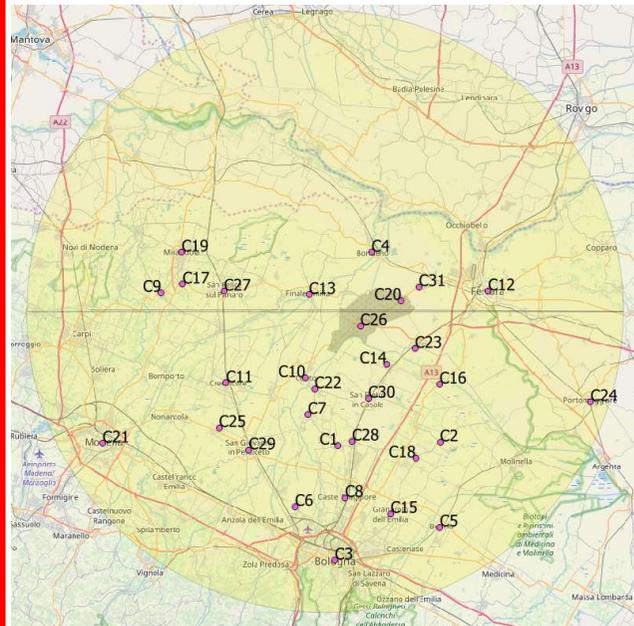
Bedrock



ROAD SERVICE DELIVERY

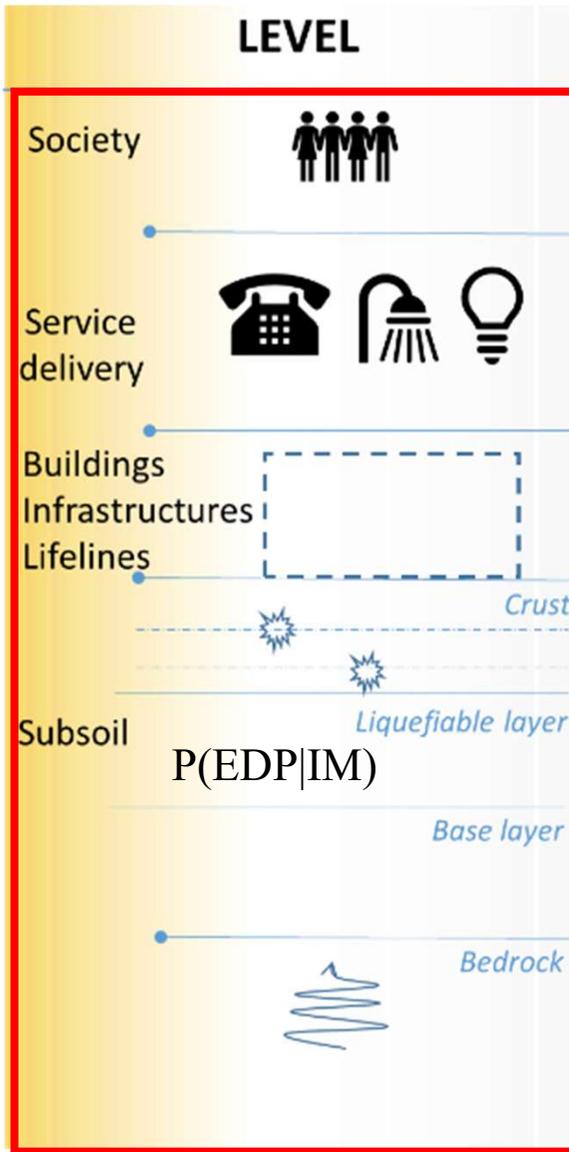


- Zone centroid
- External centroid
- Cens. Section boundary
- Zone boundary
- Basic Road Network
- Railway line



Analisi del rischio liquefazione sismo-indotta a scala urbana:
 applicazione al Comune di Terre del Reno

Bologna, 17 febbraio 2021



ROAD SERVICE DELIVERY

Damage State	PVG Displacement [m]			Serviceability limit State
	min	max	mean	
minor	0.02	0.08	0.05	useful road with speed reduction
moderate	0.08	0.22	0.15	road partially blocked -alternating direc. of travel
extensive	0.22	0.58	0.40	road totally blocked



● Minor
 Speed reduction
 $V = 30 \text{ Km/h}$

Syner-G, 2014

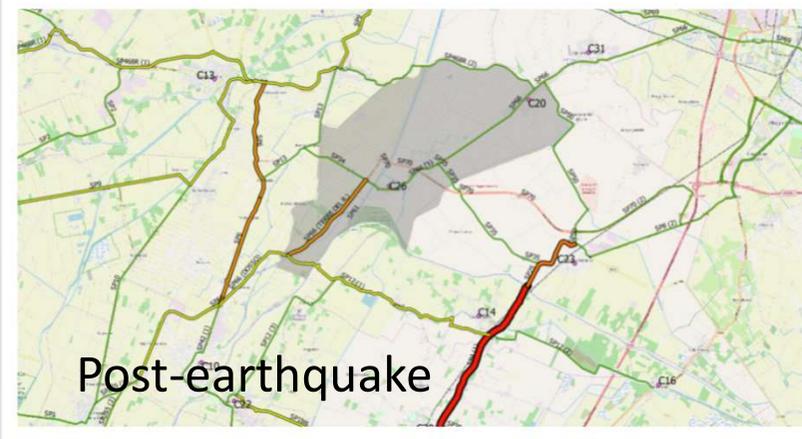
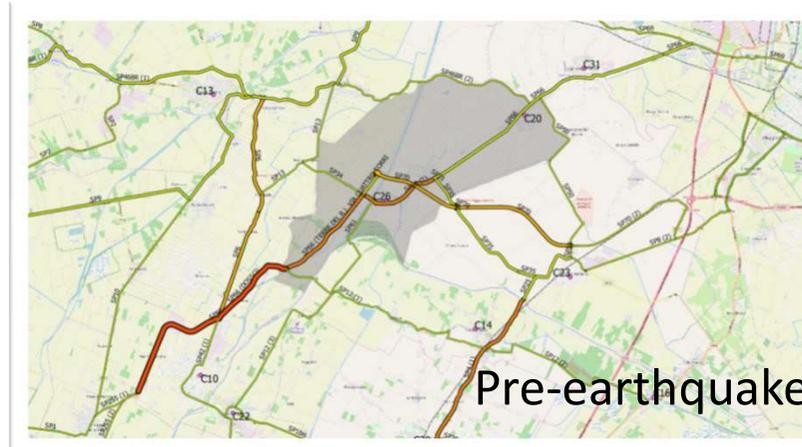
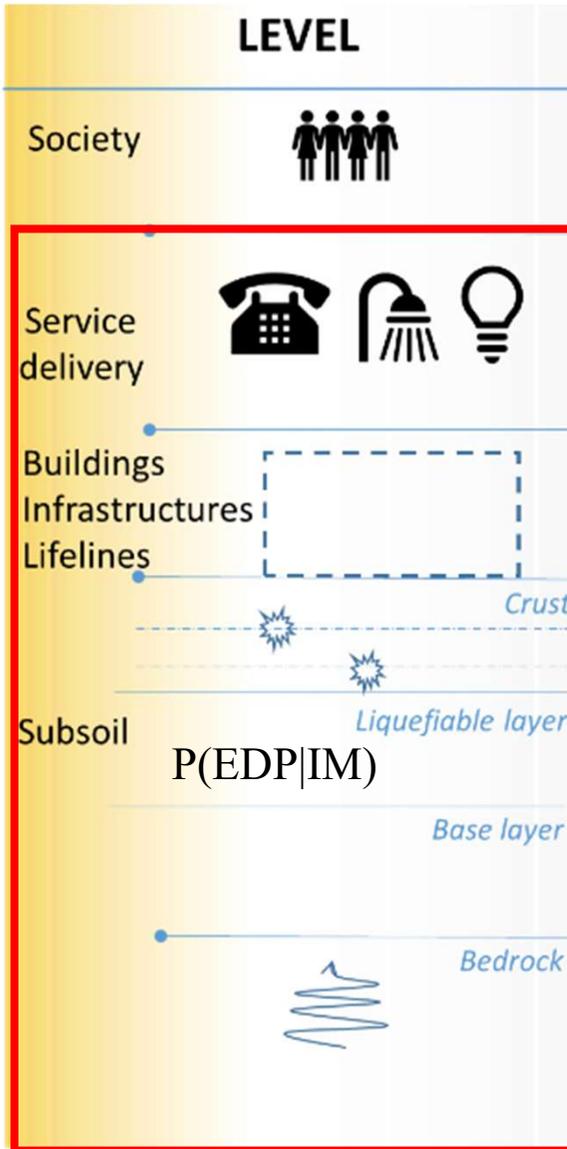
● Extensive
 Path deviation



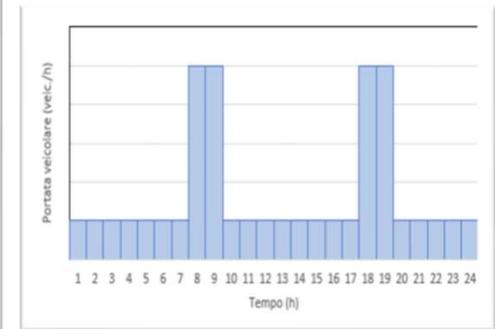
● Moderate
 Alternating
 travel
 direction



ROAD SERVICE DELIVERY



Average Daily
Traffic Delay



16 700 min

8060 euro/day



European Commission

Horizon 2020
European Union funding
for Research & Innovation

liquefact

<http://www.liquefact.eu/>



YouTube



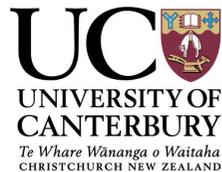
LinkedIn

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Expert
group/stakeholders

 Regione Emilia-Romagna



IL PROGETTO LIQUEFACT IN EMILIA-ROMAGNA

Webinar

Mercoledì 17 febbraio 2021



PERL

Protocollo Emilia Romagna Liquefazione



European
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