SEISMIC RISK ASSESSMENT FOR CYPRUS

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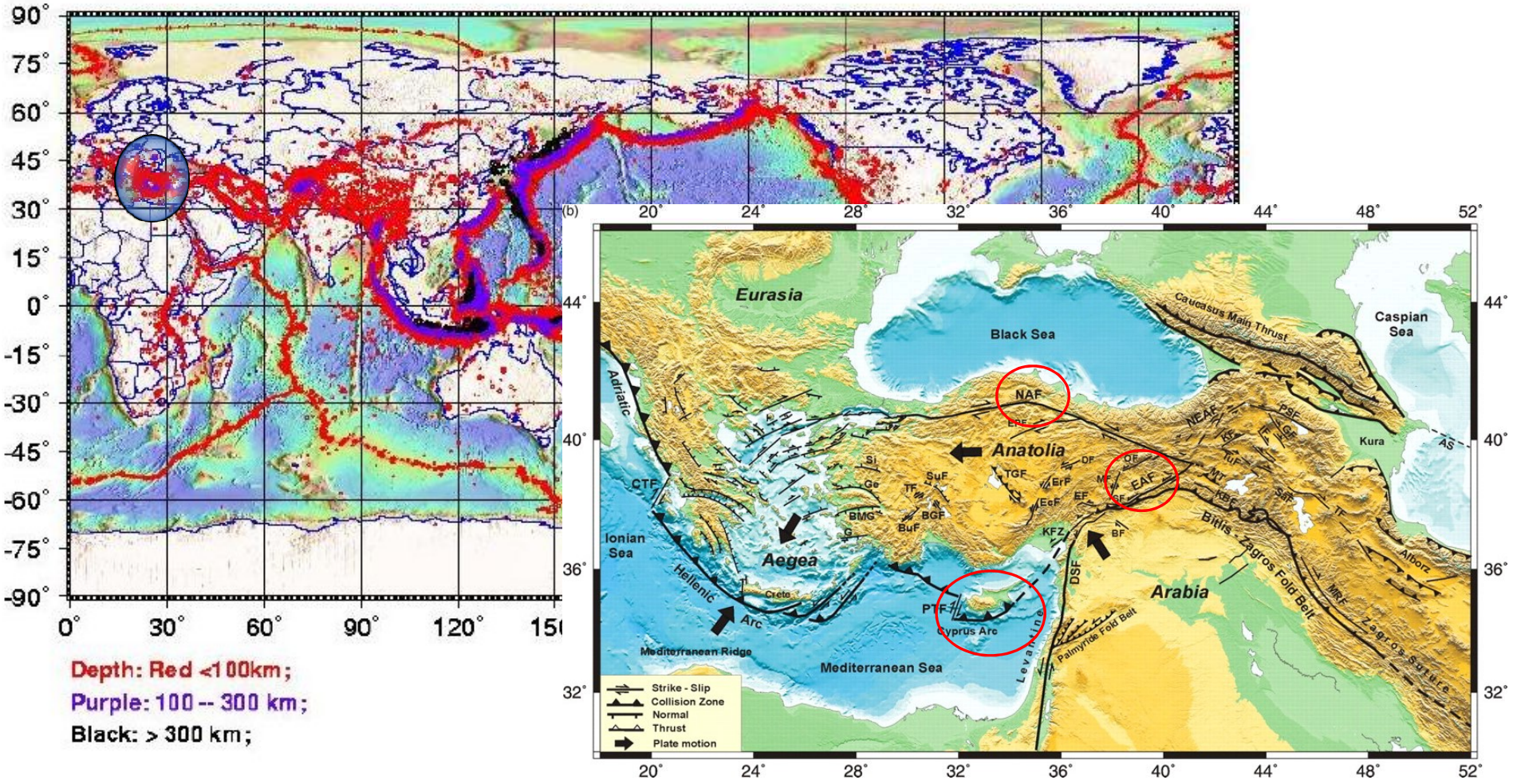
Project 004//2018: NATIONAL RISK ASSESSMENT FOR THE REPUBLIC OF CYPRUS (NRA-CY)
Project coord. Dr. Nicholas Kyriakides

PRESENTATION'S STRUCTURE

- Why do we care about earthquakes in Cyprus?
- Steps of Seismic Risk assessment
  - Seismic hazard
  - Exposure database
  - Vulnerability models
  - Probabilistic analysis
  - Scenario-based analysis
- Loss and damage estimates
- Future possibilities
- Conclusions

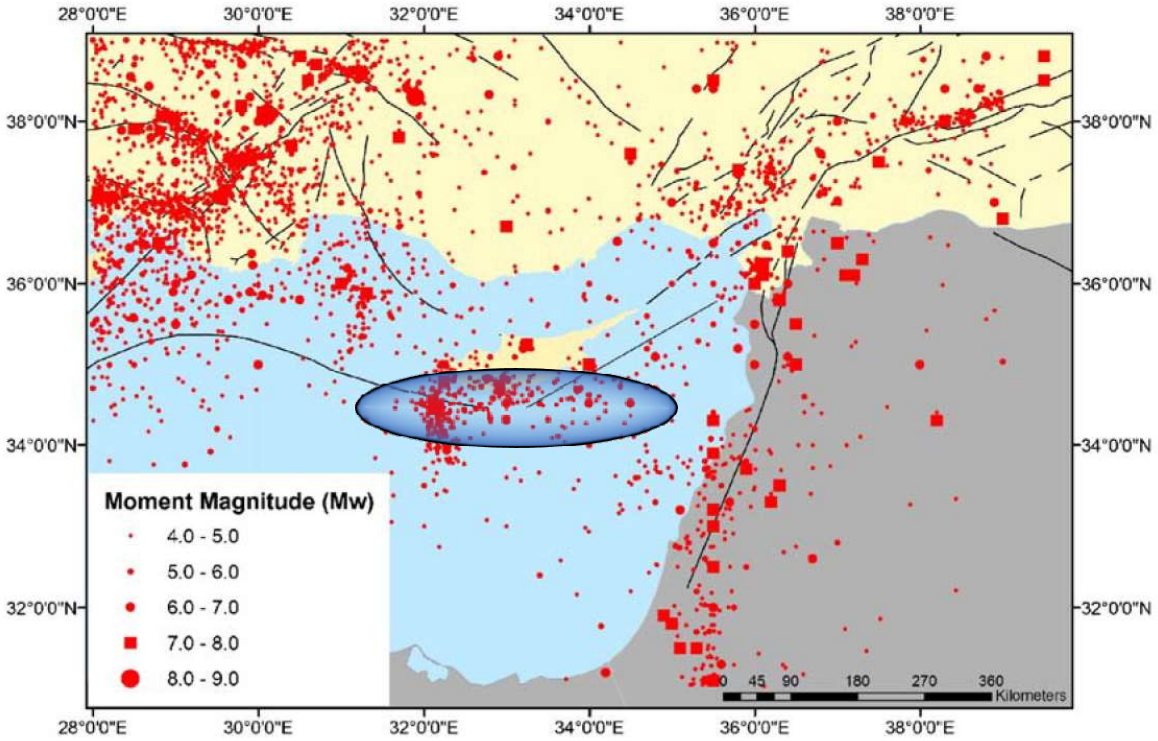
TECTONIC ENVIRONMENT OF CYPRUS



Taymaz et al. (2007)

Seismic Risk Assessment for Cyprus

SEISMICITY IN CYPRUS



Distribution of shallow earthquake epicenters in the northeastern mediterranean region from 2150 B.C. to 2006 A.D. (Cagnan and Tanircan, 2009)

- 342 with estimated magnitude of Mw= 7.4
- 1222 with Mw=6.8
- 1577 with Mw=6.7
- 1785 with Mw=7.1
- 1940 with Mw=6.7
- 1953 with Mw=6.1→ extensive damage to Paphos districts, 40 fatalities, 100 injuries
- 1996 with Mw=6.8 → limited building damage, 20 injuries
- 1999 with Mw=5.6→ 40 injuries due to panic
- 2015 with Mw=5.8 → damage to content

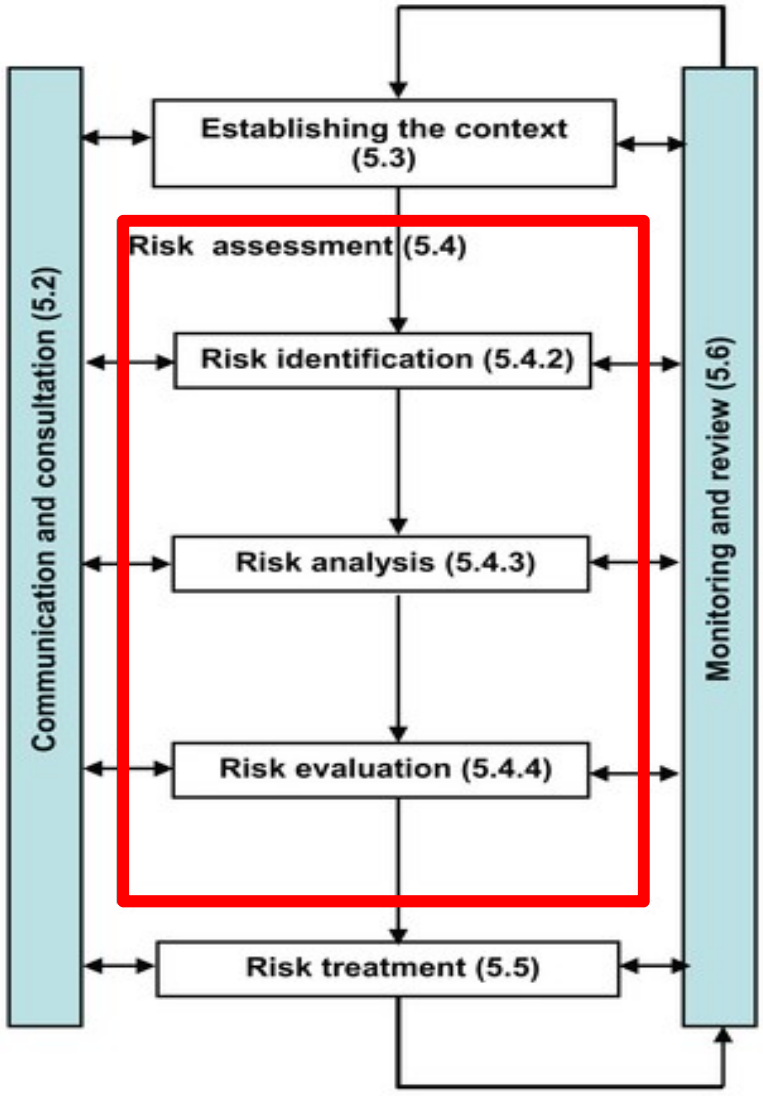
Seismic Risk Assessment for Cyprus

RISK ASSESSMENT PROCESS

Identification of potential hazard, area, exposed assets, risk metric

Convolution of risk components for definition of extent and probability of impact

Is the risk and/or its magnitude acceptable or tolerable?



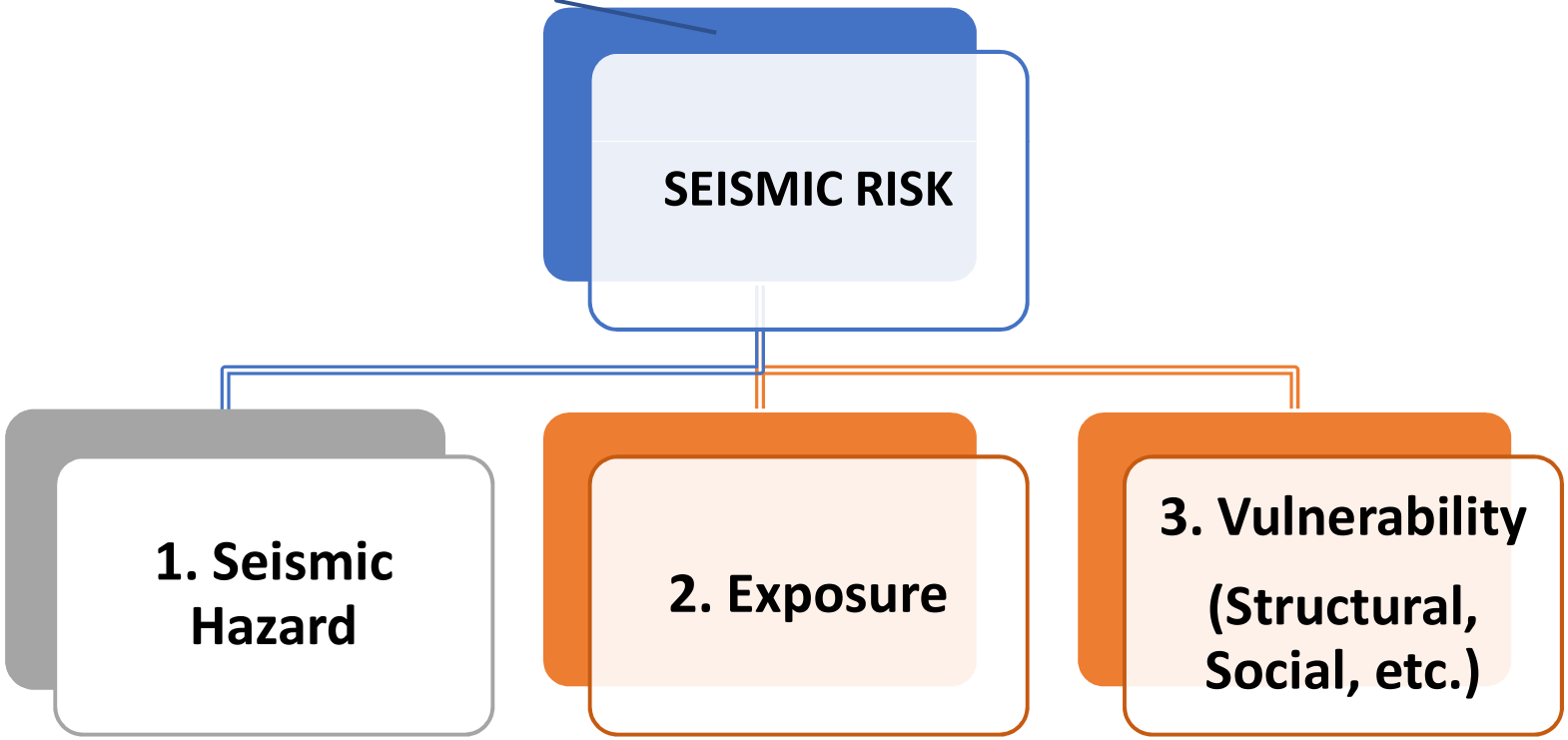
Risk Management Process – ISO 31000:2009

RISK ASSESSMENT PROCESS

NRDA of "Words into Action" UNISDR initiative to support Sendai Framework for DRR 2015-2030

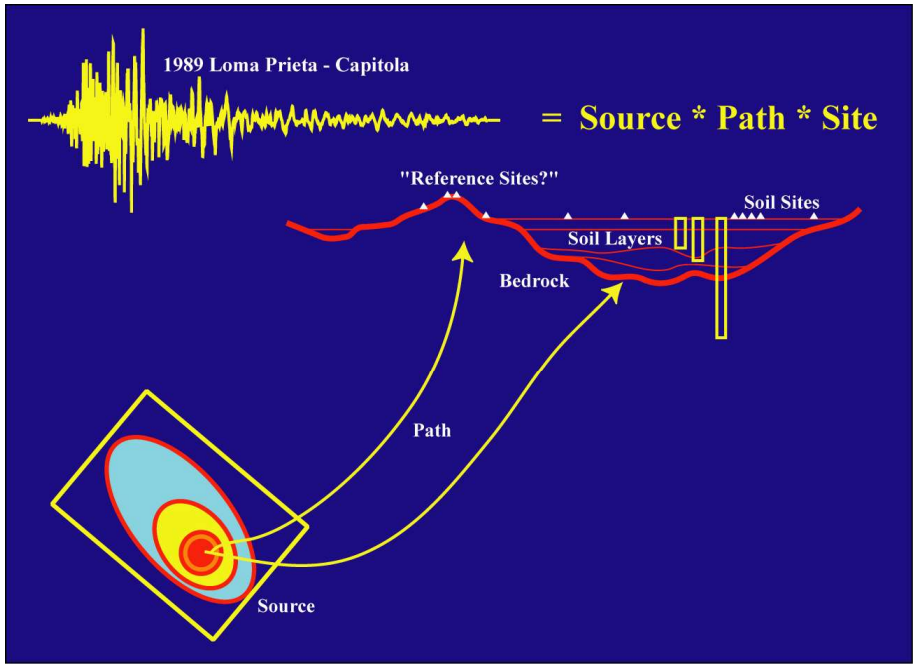
SEISMIC RISK IDENTIFICATION & ANALYSIS

The combination of the consequences of the seismic hazard in an area and the associated likelihood/probability of their occurrence (ISO 31010)



1. SEISMIC HAZARD (1/6)

Seismic Hazard refers to the likelihood and intensity of an earthquake within a given window of time, and with ground motion intensity exceeding a given threshold.



Methods

- **Qualitative** (historical mapped events & expert judgement)
- **Deterministic (DSHA)**
- **Probabilistic (PSHA)**

1. SEISMIC HAZARD (2/6)

Probabilistic (PSHA)

- identification and characterization of all hazardous sources
- description of seismicity & determination of motion intensity at each source
- probabilistic calculations towards the recurrence period of the resulted ground motion exceedance

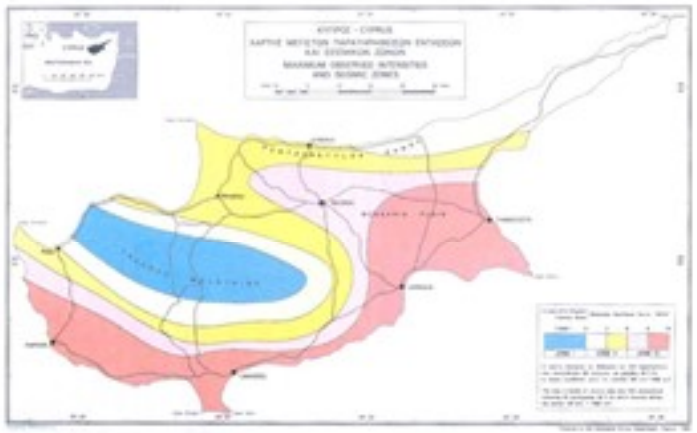
Deterministic (DSHA)

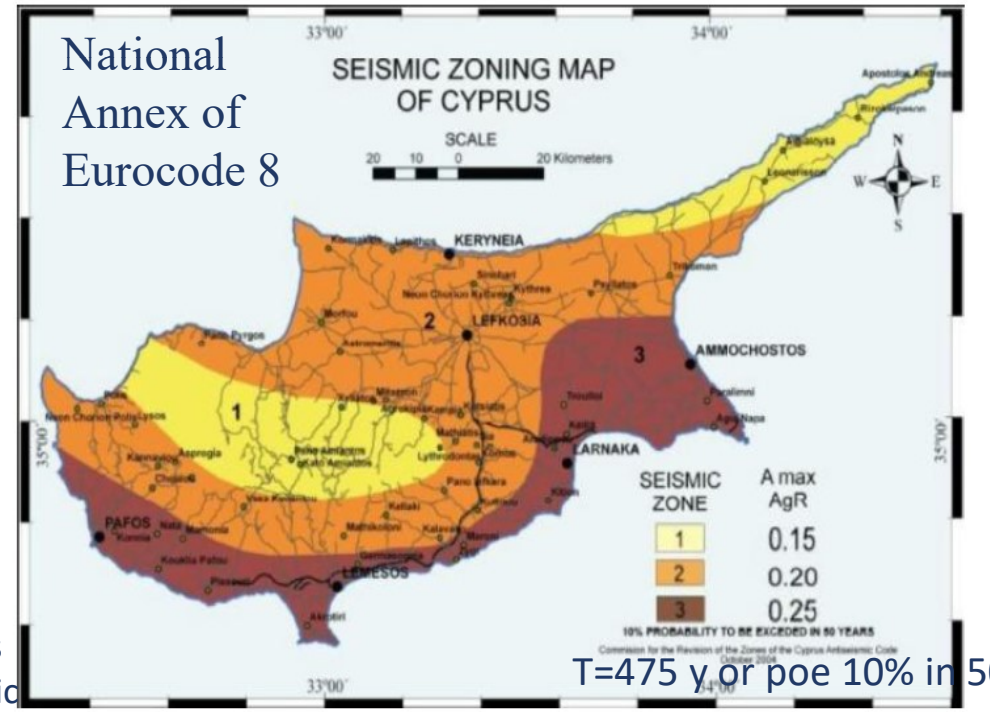
- "how the future may develop" based on a selected scenario:
  - Worst-case (MCE)
  - Most likely
  - Of specific poe
  - Simulation of past event

FAVORED for risk management

1. SEISMIC HAZARD (3/6)

Seismic zonation map evolution according to design Codes





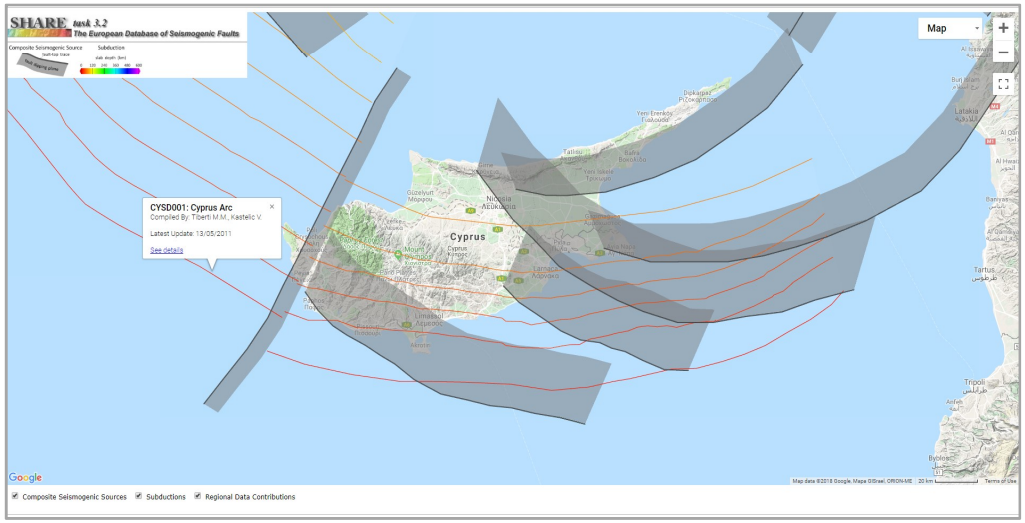
Developed by Geological Survey Department of Cyprus based on macroseismic data

T=475 y or poe 10% in 50 y

1. SEISMIC HAZARD (4/6)

The 2013 Euro-Mediterranean Seismic Hazard Model (**ESHM13**)

- **European Database of Seismogenic Faults (Basili et al., 2013)**



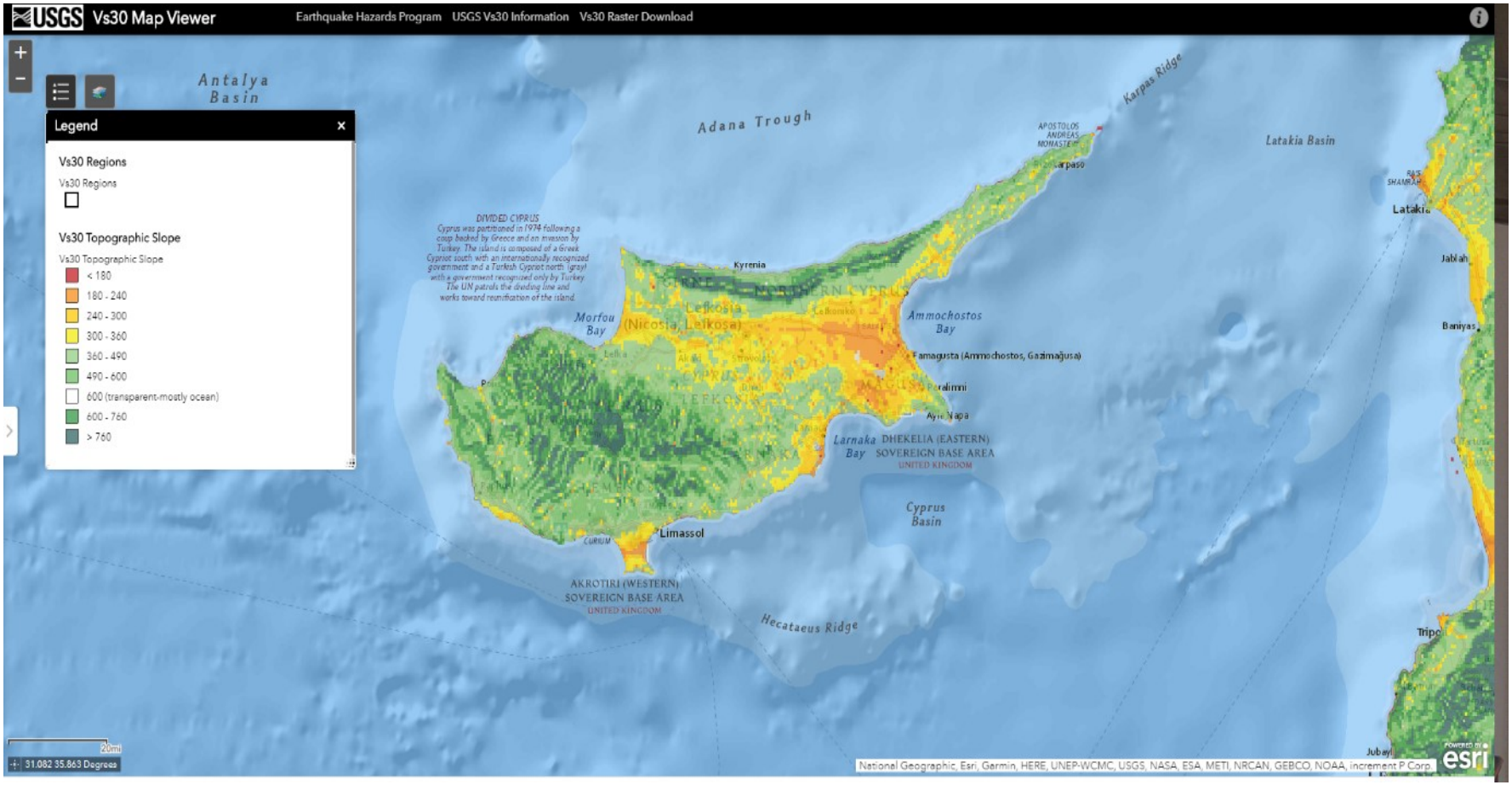
…until late 2020 when the EFSM (European Fault Source Model will be released as part of **SERA** (H2020) project and European Seismic Hazard Model (**ESHM20**).

- **SHARE European Earthquake Catalogue**
  - Compiled within SHARE (Giardini et al., 2013) and EMME (Erdik et al., 2012) projects
  - Includes seismic catalogue between 1000 and 2006 with 6170 events

- **Strong Motion Database**
  - By Yenier et al., 2010
  - Several global Databases
  - Covers earthquakes from 1930s to 2009 with2448 events and 14193 records

1. SEISMIC HAZARD (5/6)

Site conditions



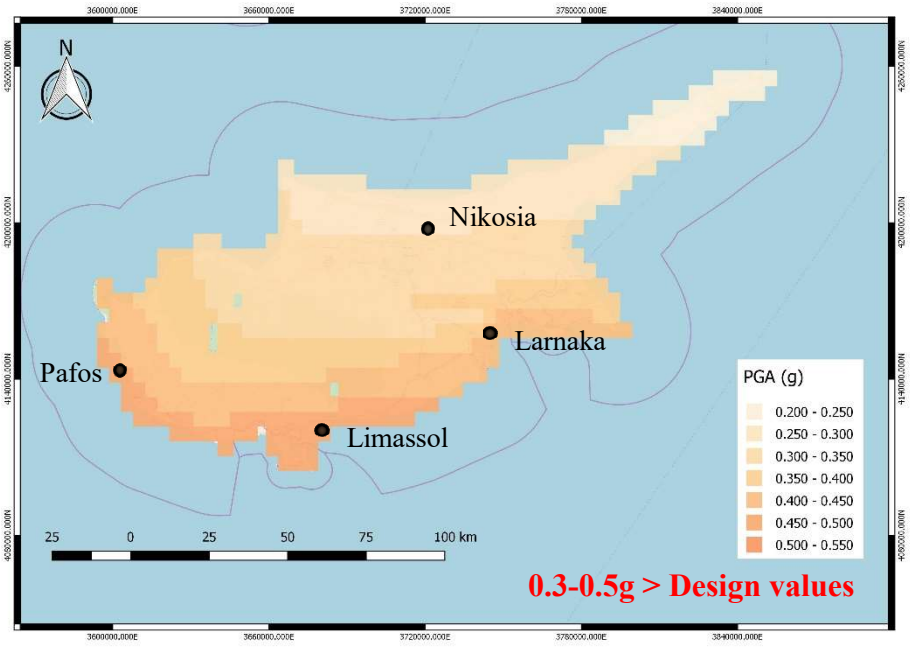
(Cohen et al., 2012)

1. SEISMIC HAZARD (6/6)

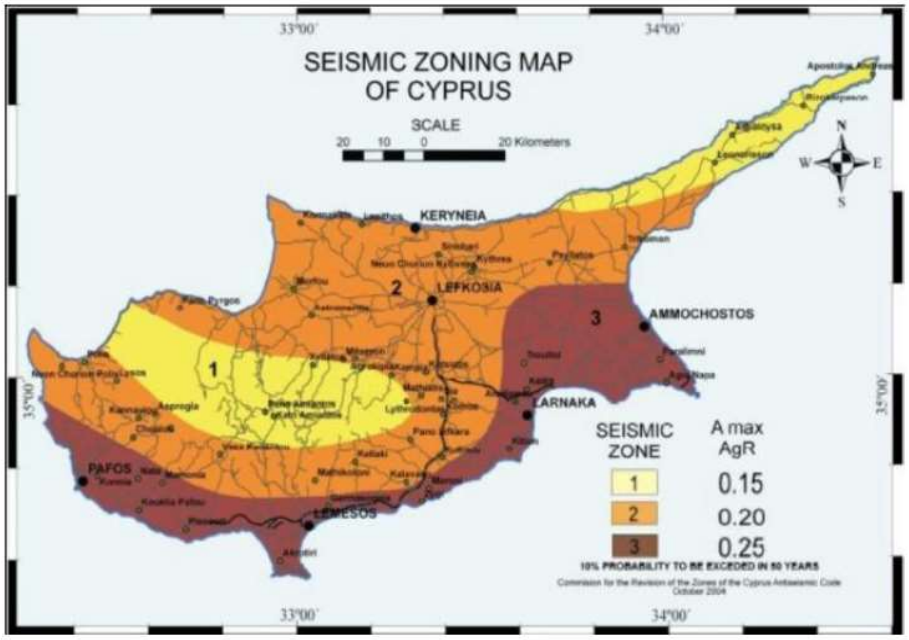
From European SHARE project (Giardini et al., 2013)

Incl. 3 seismic source models, several GMPEs, Vs30 from USGS
Classical PSHA with OpenQuake platform (GEM tool)

T = 475 y or poe 10% in 50y



National Annex of EC8



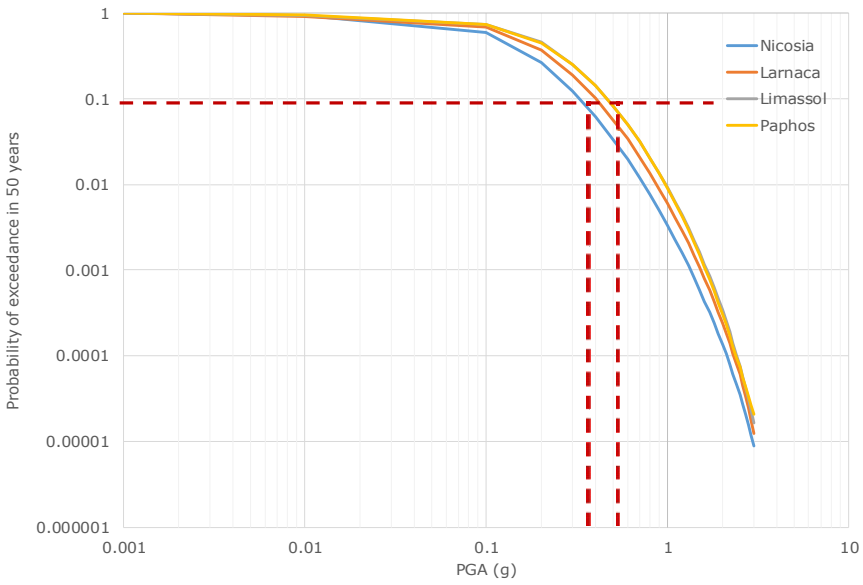
1. SEISMIC HAZARD

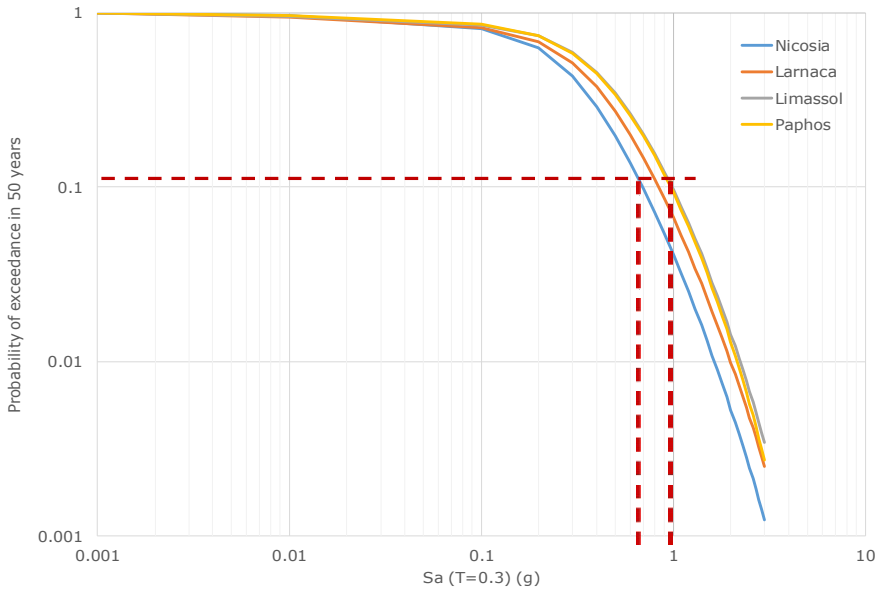
- Seismic Source models (per SHARE)
- Classic Area source model
- Fault-source and background model
- SEIFA model

- Ground motion model (per SHARE)
- Akkar & Bommer, 2010
- Cauzzi & Faccioli, 2008
- Chiou & Youngs, 2008
- Zhao et al., 2006
- Lin&Lee, 2008
- Atkinson & Boore, 2003

1. SEISMIC HAZARD

Seismic hazard curves form PSHA





2. EXPOSURE DATABASE (1/2)

Exposure: “people, property, systems, or other elements present in hazard zones that are subject to potential losses” (UN, 2015)

- Time construction period
- Construction material
- Structural bearing system
- Number of floors
- Irregularities
- Use

Types of data

- GIS grid 1x1km^2
- Building descriptive data (CENSUS 2011, Department of Lands and Surveys)
- Population data (CENSUS 2011)

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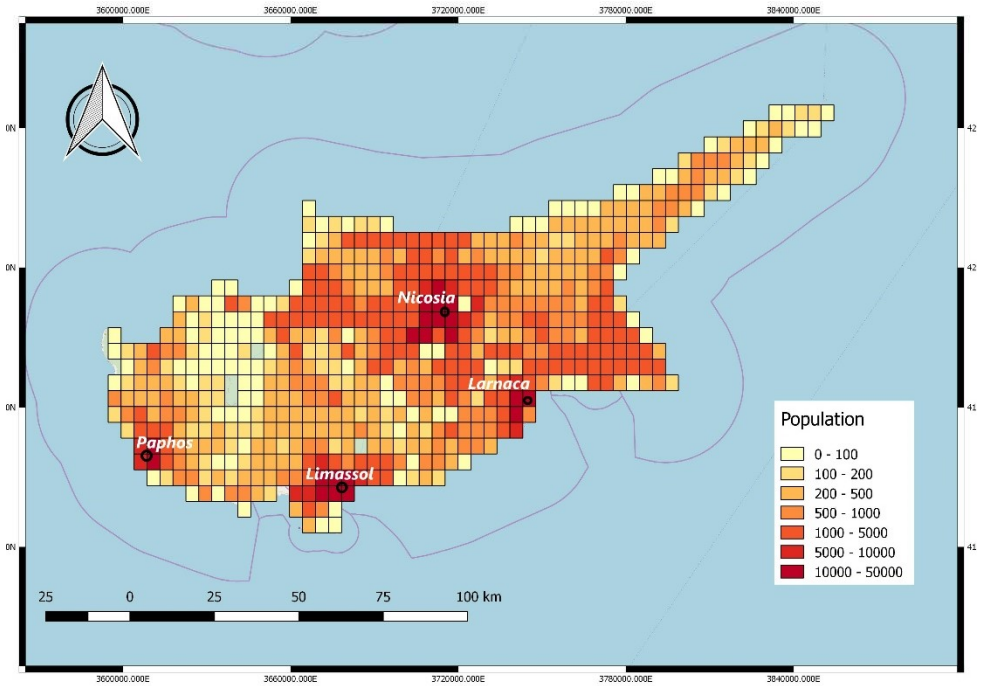
Exposure: “people, property, systems, or other elements present in hazard zones that are subject to potential losses” (UN, 2015)

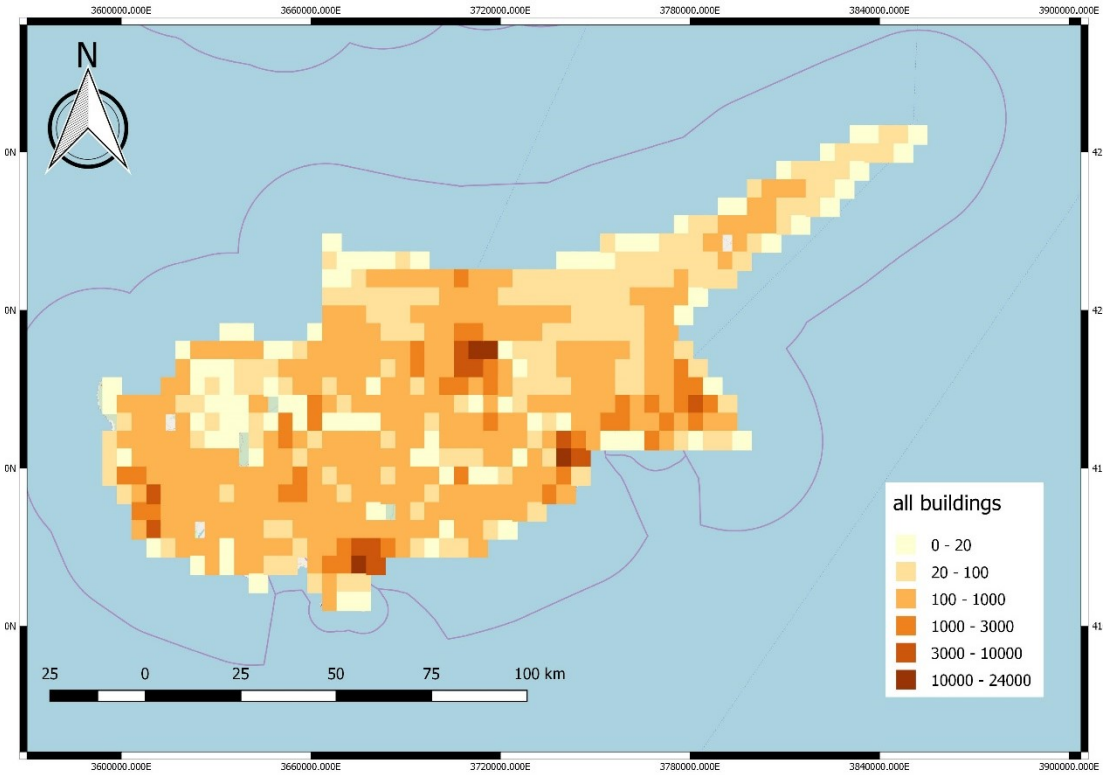


Types of data

- GIS grid 1x1km^2
- Building descriptive data (CENSUS 2011, Department of Lands and Surveys)
- Population data (CENSUS 2011)

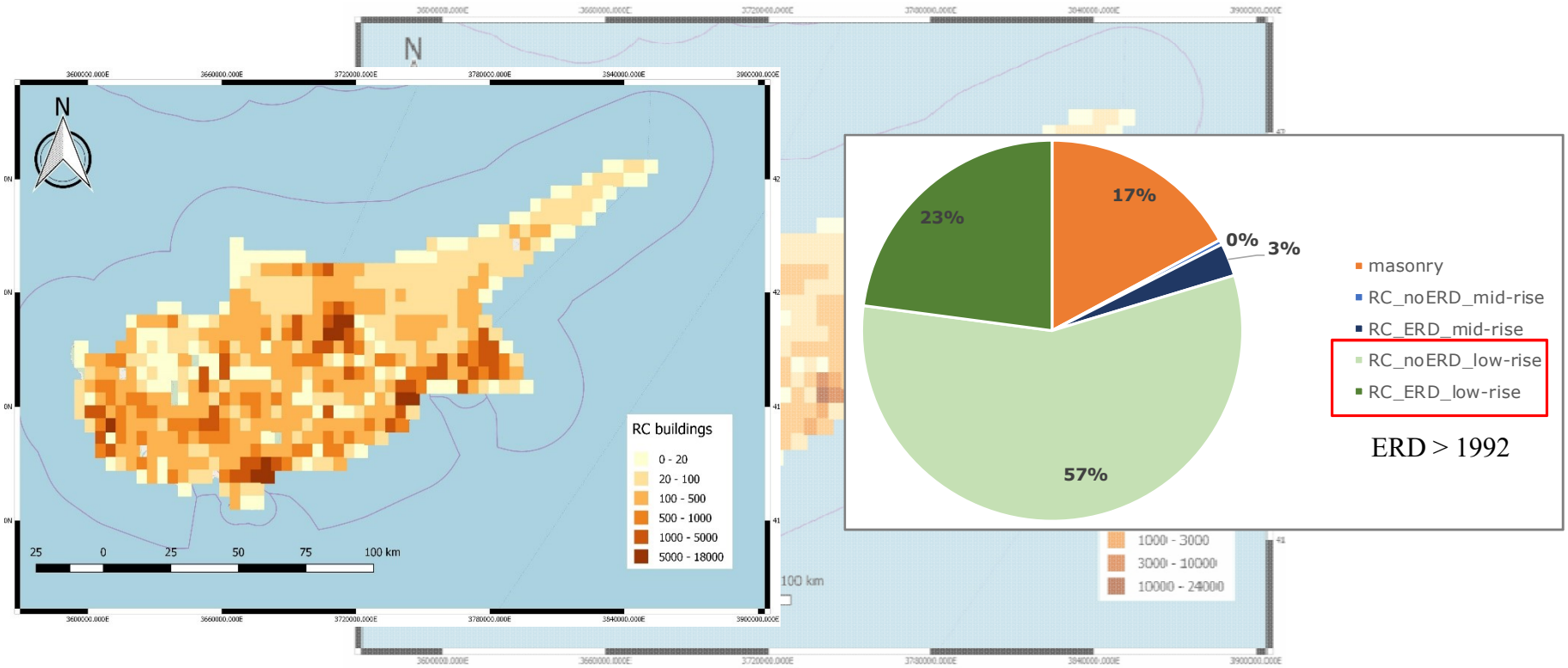
DKF3

2. EXPOSURE DATABASE (2/2)



(Chrysostomou et al.,2014)

2. EXPOSURE DATABASE (2/2)



(Chrysostomou et al.,2014)

3. VULNERABILITY (1/2)

Vulnerability: the conditions determined by physical, social, economic, and environmental factors or processes which increase the susceptibility of a community to the impact of hazards (Sendai Framework 2015)

Physical

- Expected resistance of a structure exposed to the seismic hazard
- Intrinsic parameter
- Independent of hazard
- Depends on structural, mechanical, geometric building characteristics

Social

- Concept that assists to identify those characteristics of population that enable them to respond and recover
- Dynamic & ever-changing
- Composite index composed by parameters
- Integrated or holistic risk mapping

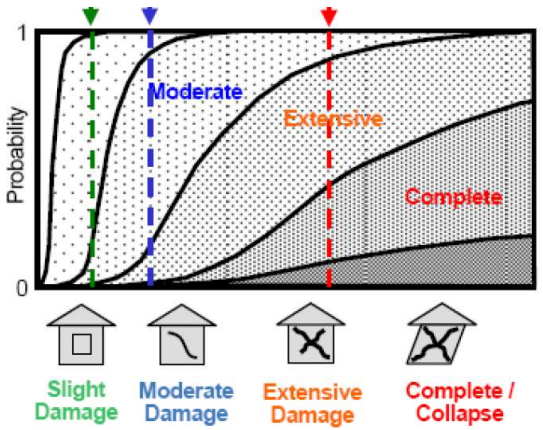
3. PHYSICAL VULNERABILITY (2/2)

Empirical

Hybrid

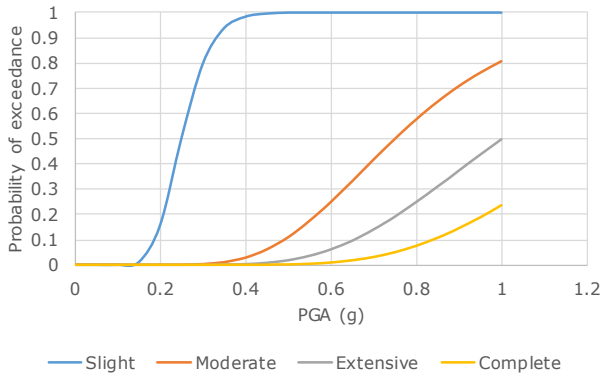
Analytical

Fragility curves

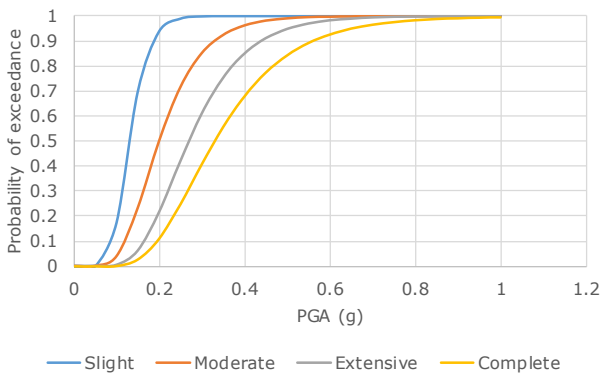


420 TH analyses
All building typologies
Parametric study
Kyriakides et al. (2015)

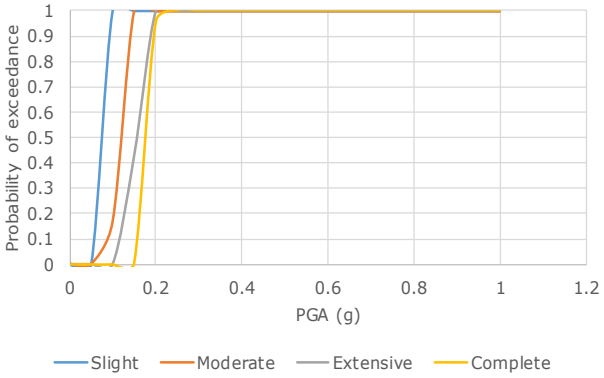
RC with ERD low rise



RC without ERD low rise



Masonry without ERD low rise

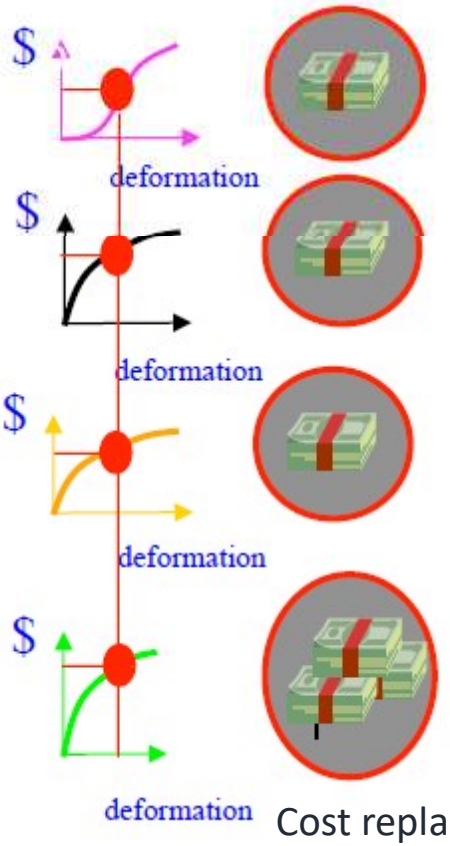


LOSS FUNCTIONS (1/2)

Probability of occurrence per damage state

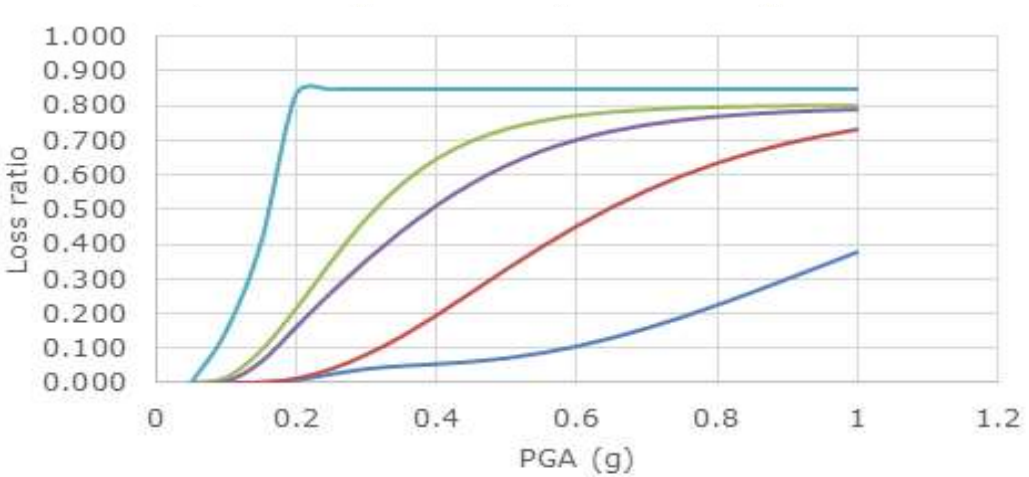
✖

Loss ratio or damage functions ✖ Initial value



Cost replacement new 600-800€/m²

Spect
Accel



nent

Loss ratios

	Slight	Moderate	Extensive	Complete
RC	0.05	0.2	0.45	0.8
Masonry	0.12	0.3	0.55	0.85

ent for Cyprus

LOSS FUNCTIONS (2/2)

- Human Loss: modelling casualties
  - HAZUS (1999) injuries model and Coburn and Spence fatalities model

Casualty rates	Slight (%)	Moderate (%)	Extensive (%)	Collapse (%)
Reinforced Concrete	0.0	0.03	0.10	1.0
Masonry	0.0	0.10	0.20	2.0

- Human Loss: displaced population
  - Population from Extensively and Completely damaged buildings are expected to evacuate
  - 50% of evacuees are expected to seek public sheltering (empirical) (PACES project & Kazantzidou et al. 2018)
  - Social vulnerability study from better estimate

LOSS FUNCTIONS

- Fatalities: $K_S = [M_1 \cdot M_2 \cdot M_3 \cdot (M_4 + M_5 \cdot (1 - M_4))]$ (Spence, 2007 & LESSLOSS)
  x P(ds_i) x Population
  Depending on occupancy rate, building use, ratio of trapped inhabitants, correlation of collapse with fatalities, day/night scenario

- Injuries: $P_{Sev.2} = [P(ds_S)*P_{Sev,2\_S} + P(ds_M)*P_{Sev,2\_M} + P(ds_E)* P_{Sev,2\_E} + P(ds_C)*P_{Sev,2\_C}] * M_2$
  x Population (Hazus, 1999)

  Day/night

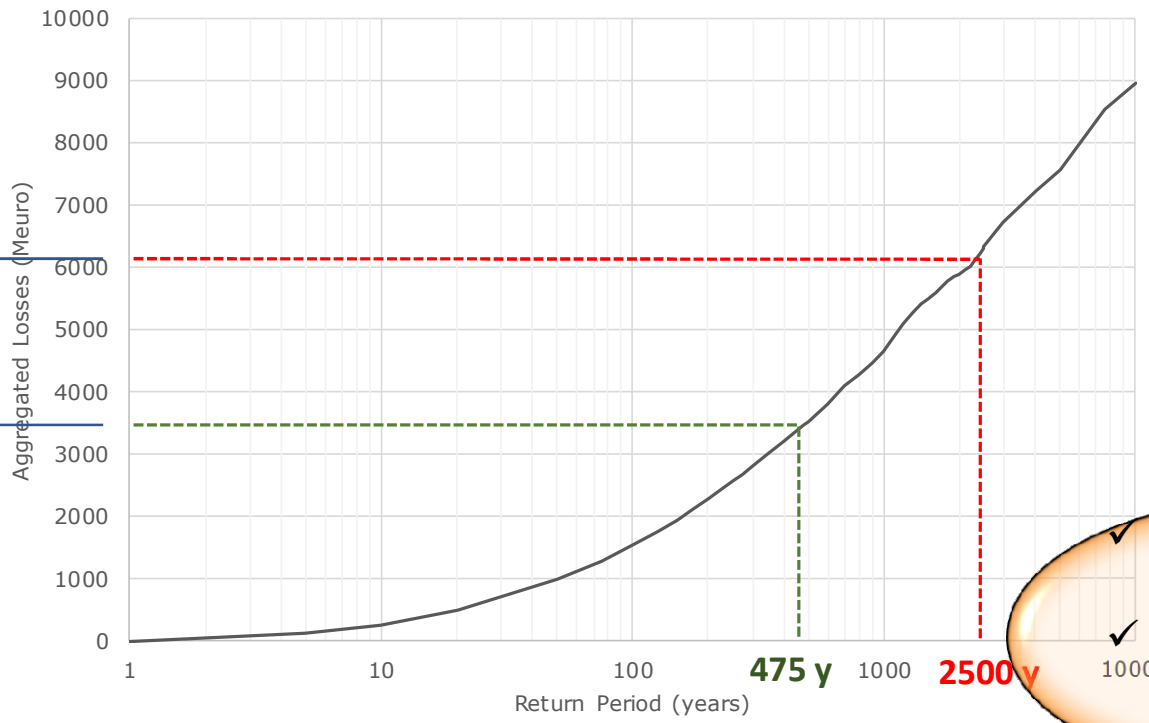
  Casualty rates

Psev,2_i	Slight (%)	Moderate (%)	Extensive (%)	Collapse (%)
Reinforced Concrete	0.0	0.03	0.10	1.0
Masonry	0.0	0.10	0.20	2.0

- Displaced population: $\#DP_L = \{p[ds_E] + p[ds_C]\} \cdot Population$ (HAZUS, 1999 & PACES)
  Long-term x 50% → will seek public sheltering

PROBABILISTIC LOSS ESTIMATES

Loss exceedance curve



Scenario 2500 y
- Fd for important (infra)structures

Scenario 475 y
- Fd for normal structures

Stochastic event based analysis for 50.000 years (OpenQuake v3.2)

✓ Order of magnitude!
✓ To consider uncertainties of area extent

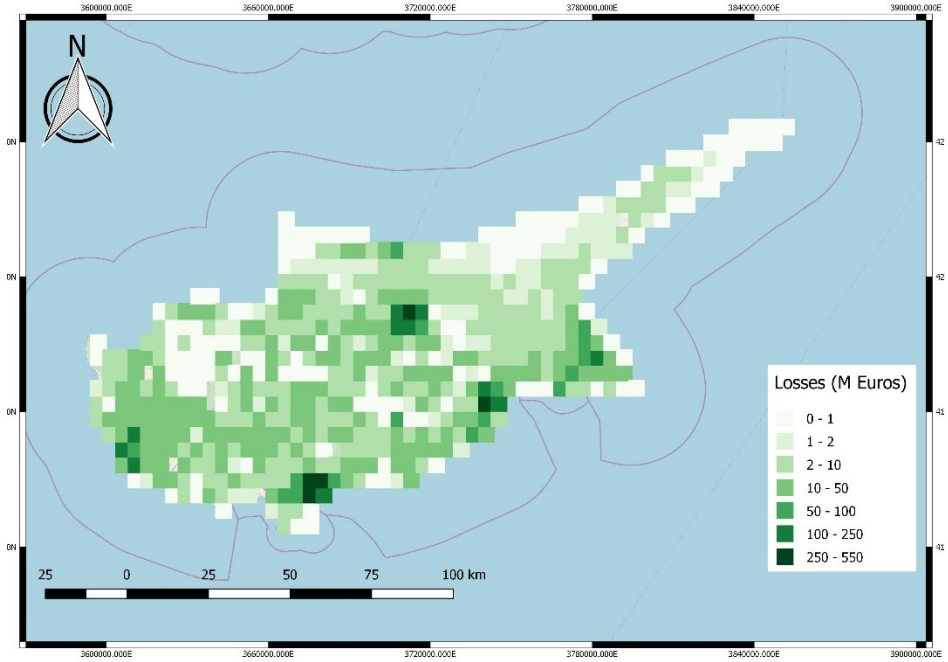
Total repl. Value=32 billion €

Average Annual Loss (mean values)

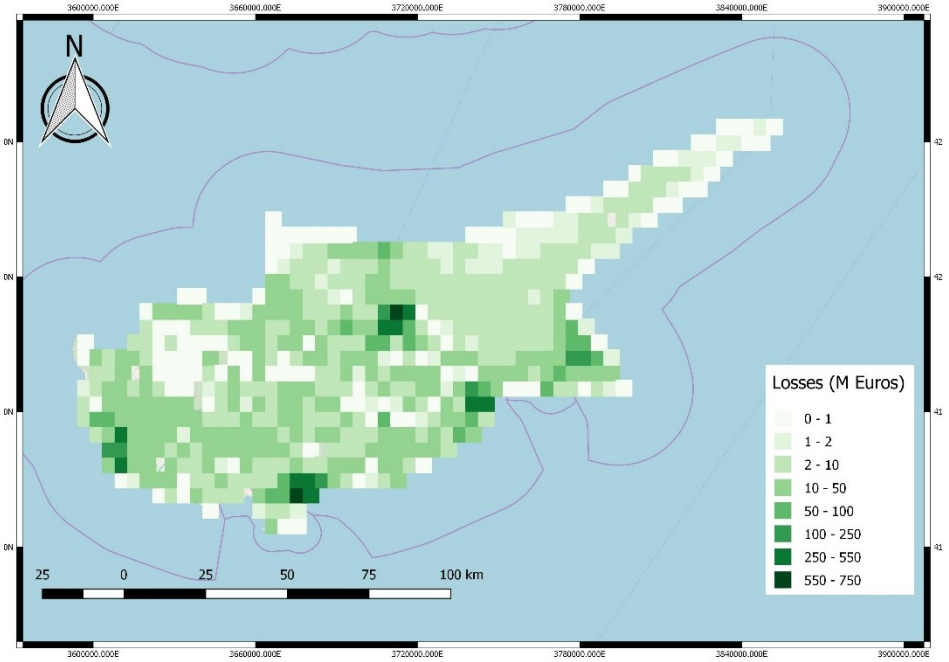
	Total	Nicosia	Larnaca	Limassol	Paphos
AAL (€)	116M	13.0M	8.7M	23.6M	9.0M
AALR	0.36%	0.31%	0.44%	0.69%	0.63%
Population	1,022,406	143,558	37,771	127,629	40,012

PROBABILISTIC LOSS DISTRIBUTION

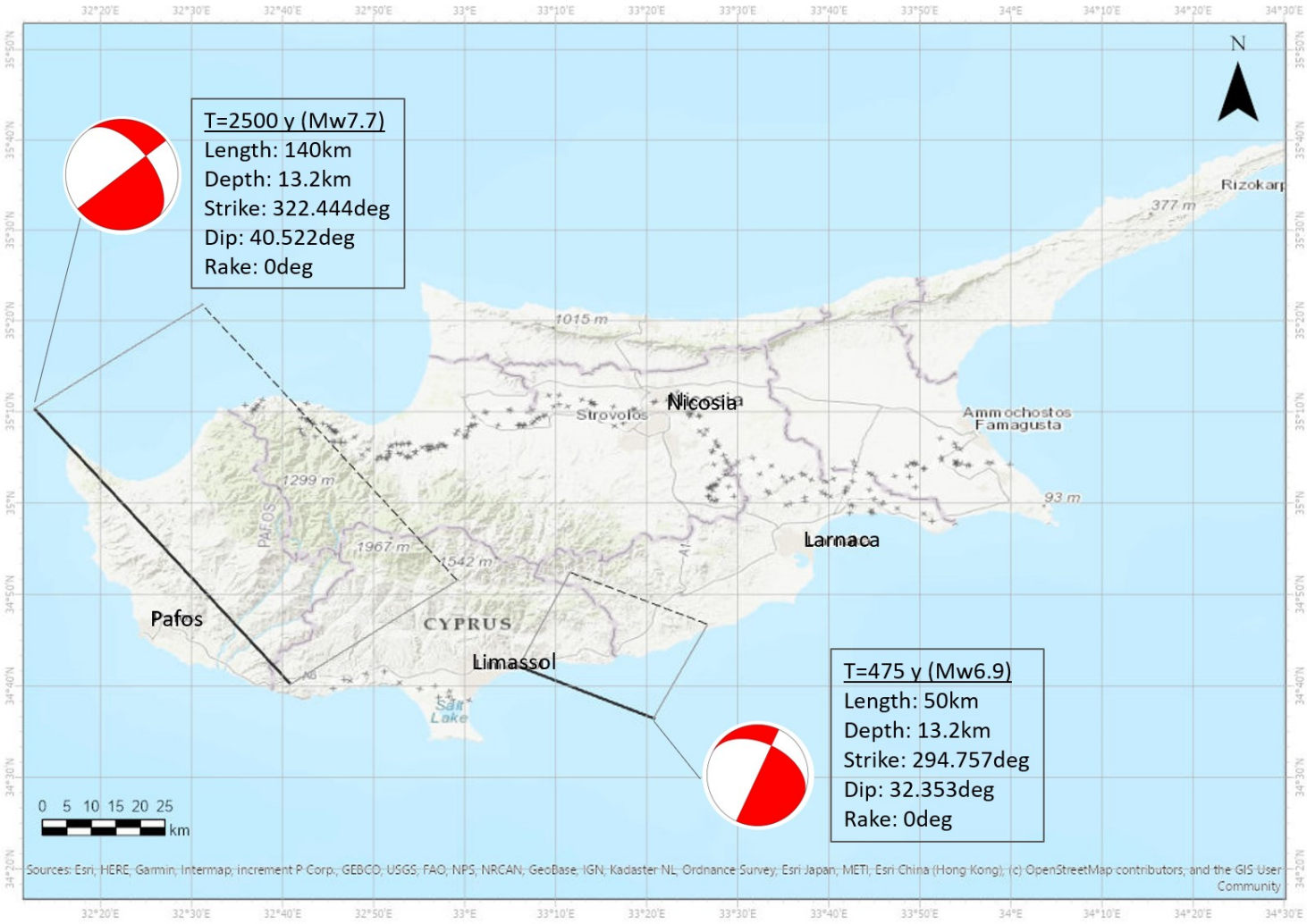
Loss map for T=475 y or poe 10% in 50y



Loss map for T=2500 y or poe 2% in 50y

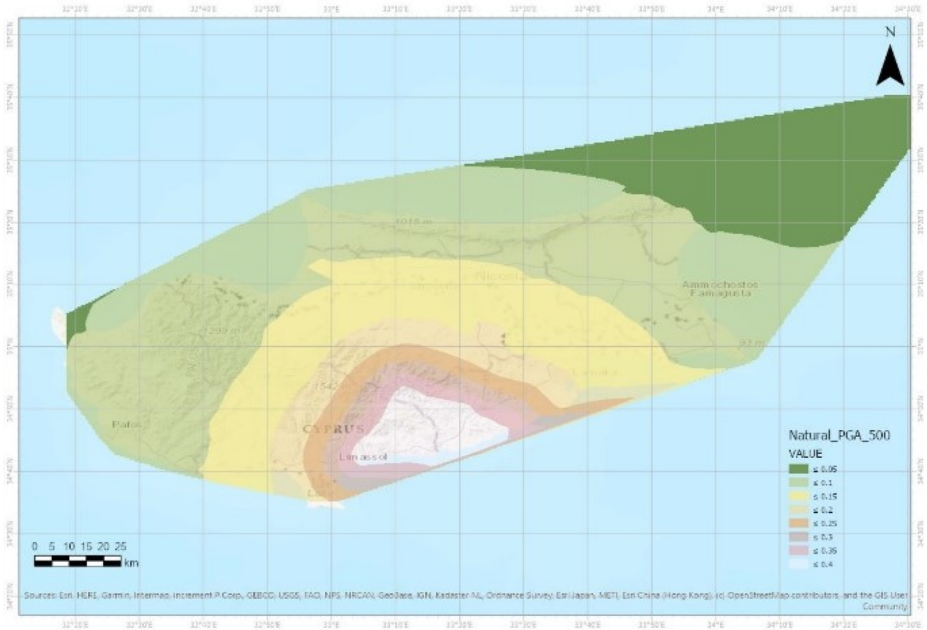


SCENARIO-BASED ANALYSIS

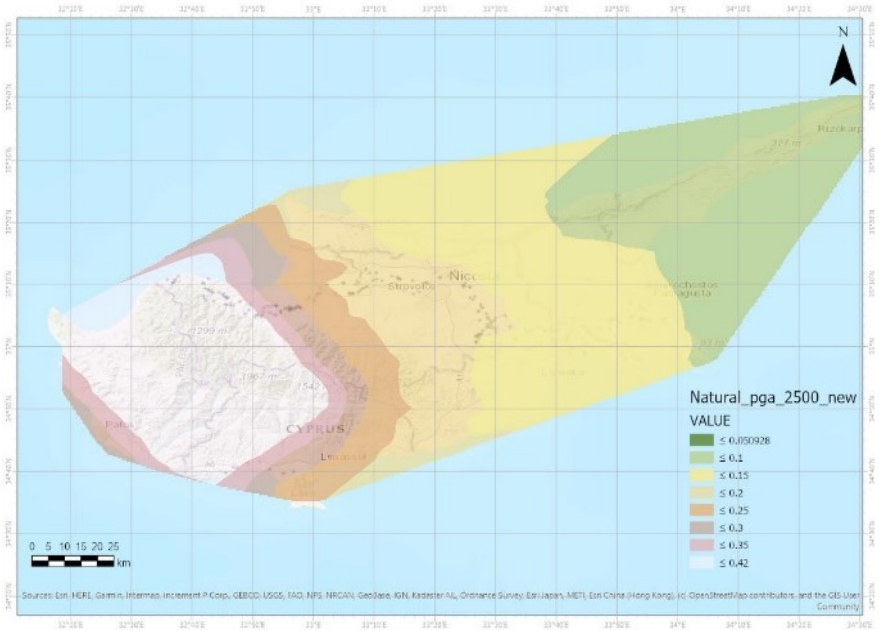


SEISMIC HAZARD FOR SCENARIOS

Scenario for T=500 years

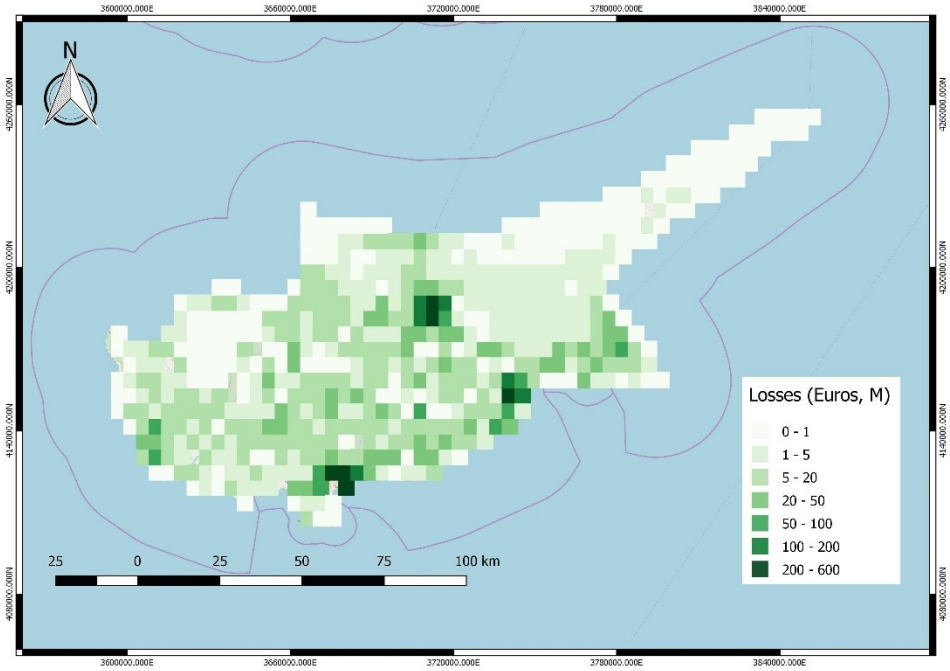


Scenario for T=2500 years

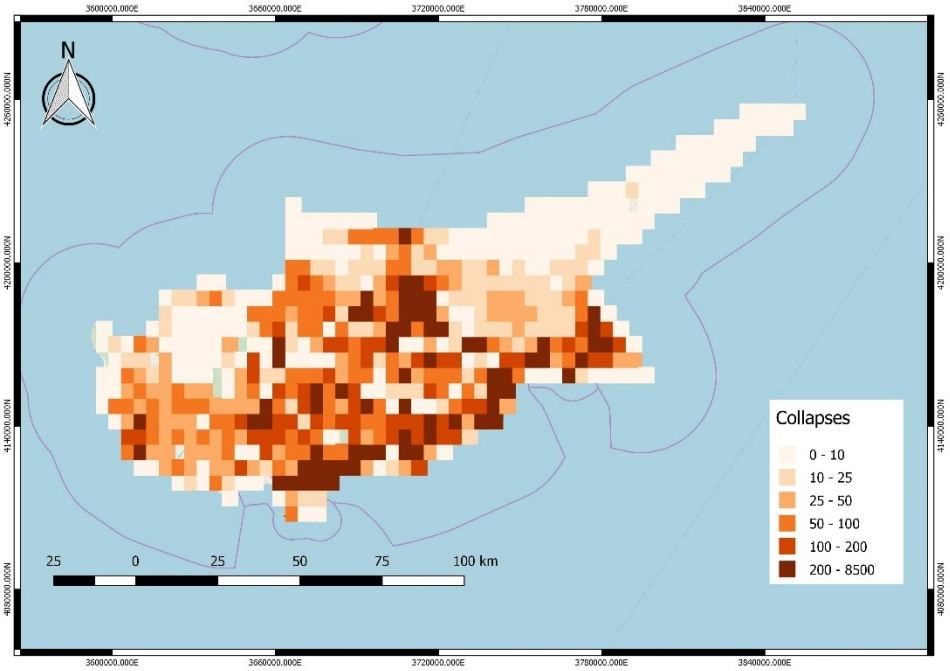


LOSS & DAMAGE FOR SCENARIO T=475 Y

Loss distribution in M euro

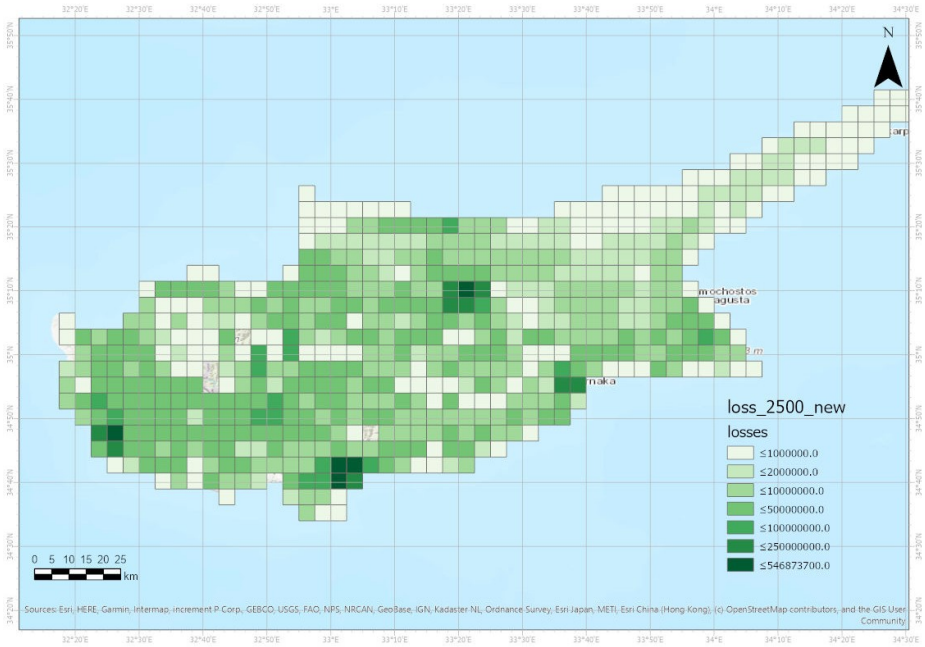


Collapse distribution in no# buildings

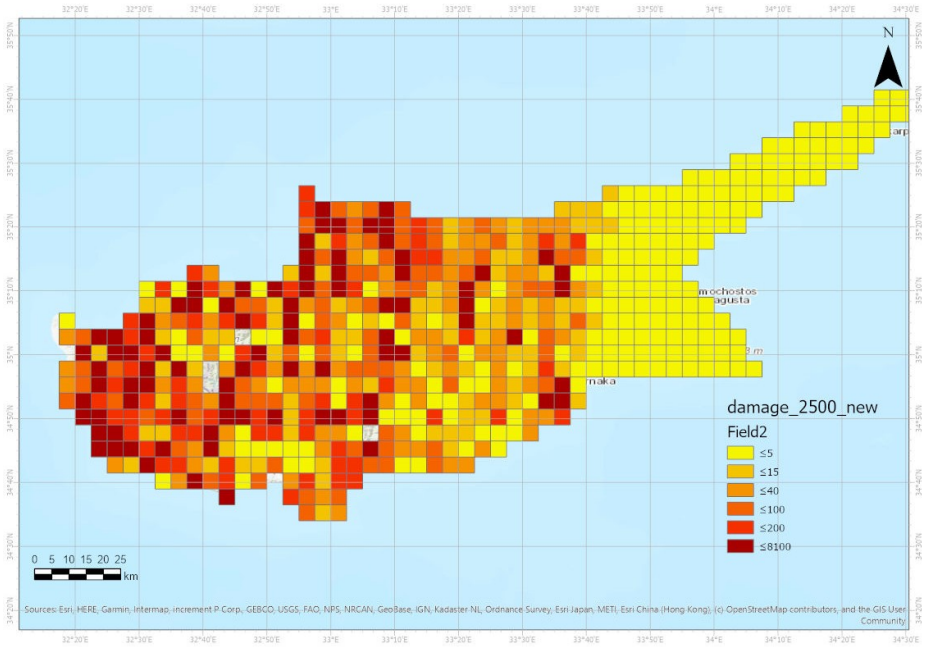


LOSS & DAMAGE FOR SCENARIO T=2500 Y

Loss distribution in M euro

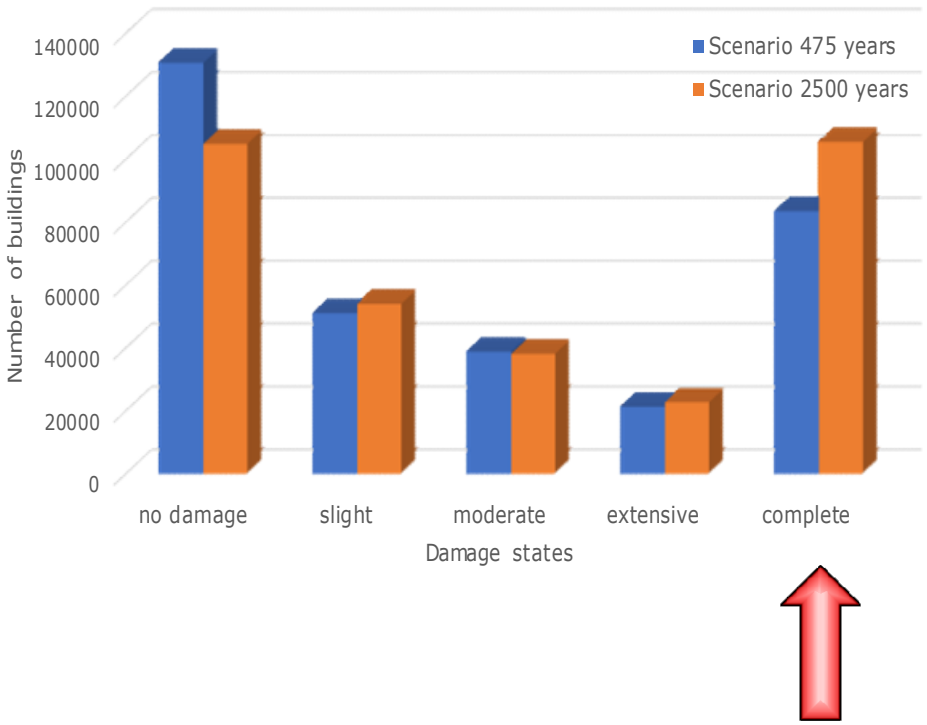


Collapse distribution in no# buildings

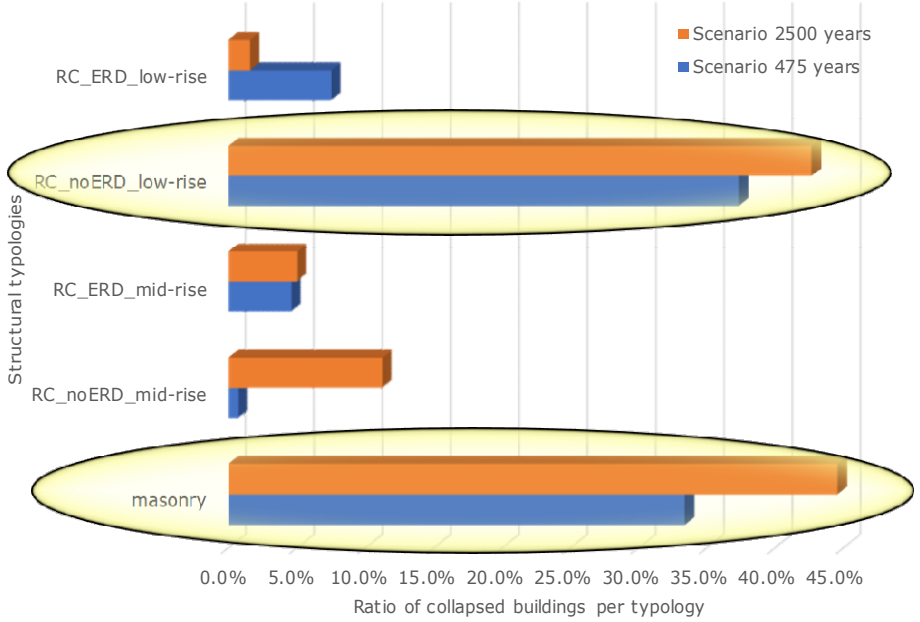


DAMAGE ESTIMATE FOR SCENARIOS

Number of buildings per damage state

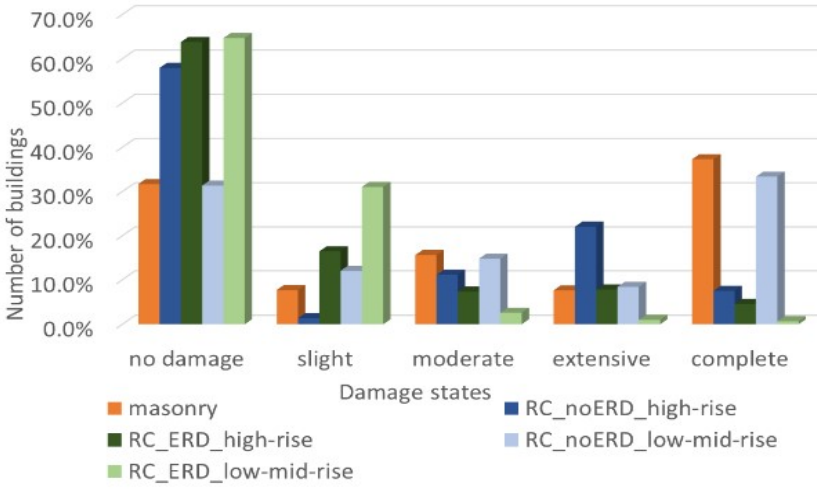


Ratio of collapsed buildings

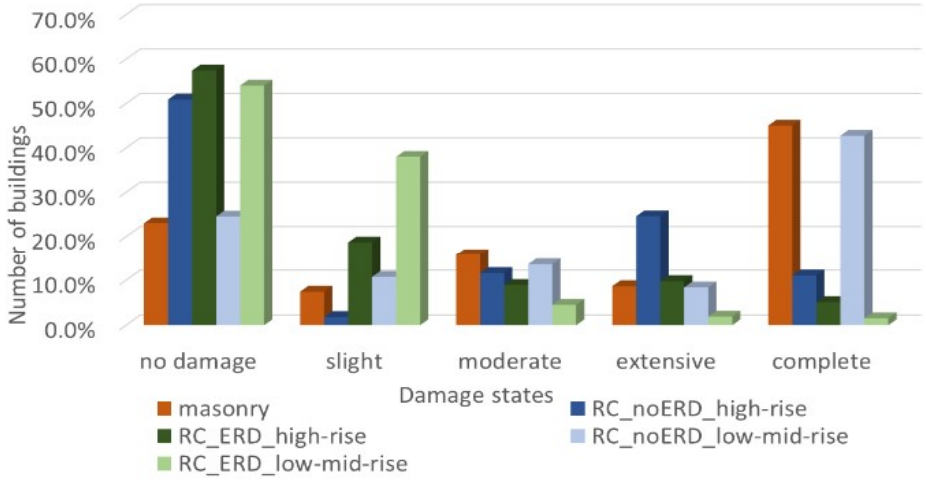


DAMAGE ESTIMATE FOR SCENARIOS

Scenario T=475 years



Scenario T=2500 years



	Total	Nicosia	Larnaca	Limassol	Pafos
Scenario T=475y	7.7B	1.1B	530M	1.6B	150M
Scenario T=2500y	9.5B	1.1B	363M	1.3B	645M

LOSS ESTIMATE FOR SCENARIOS

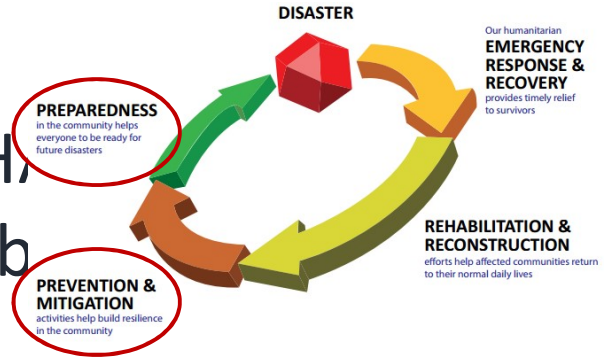
Cities	Injuries				Fatalities			
	475 years		2500 years		475 years		2500 years	
	People	Ratio (%)	People	Ratio (%)	People	Ratio (%)	People	Ratio (%)
Nicosia	20-50	0.01-0.10	30-70	0.06-0.14	6-8	0.01-0.02	12-15	0.02-0.03
Larnaca	25-60	0.07-0.16	10-25	0.03-0.07	7-10	0.02-0.03	4-5	0.01
Limassol	110-220	0.20-0.40	65-150	0.13-0.27	30-50	0.06-0.09	30-40	0.05-0.08
Paphos	3-10	0.01-0.03	75-175	0.23-0.52	1	0.00	30-45	0.09-0.13
Total	730-1500	0.07-0.15	880-1780	0.09-0.17	200-300	0.02-0.03	380-550	0.04-0.05

Displaced population (both scenarios): **93.000 – 110.000**

Order of magnitude!

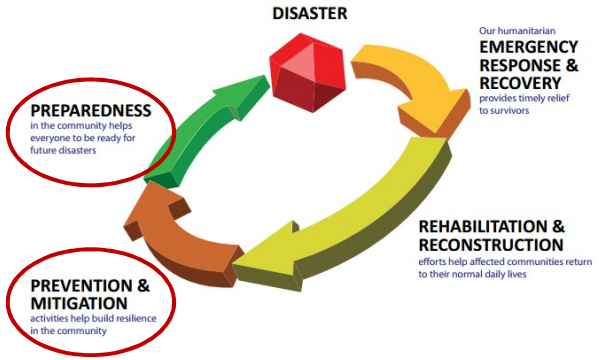
CONCLUSIONS

- Seismic risk assessment provides loss estimation (monetary, human) for prioritization of disaster management, budget allocation, mitigation measurements, emergency and healthcare provisions.
- Scenario-based analysis after PSHA comprehensive and understandab management purposes.



CONCLUSIONS

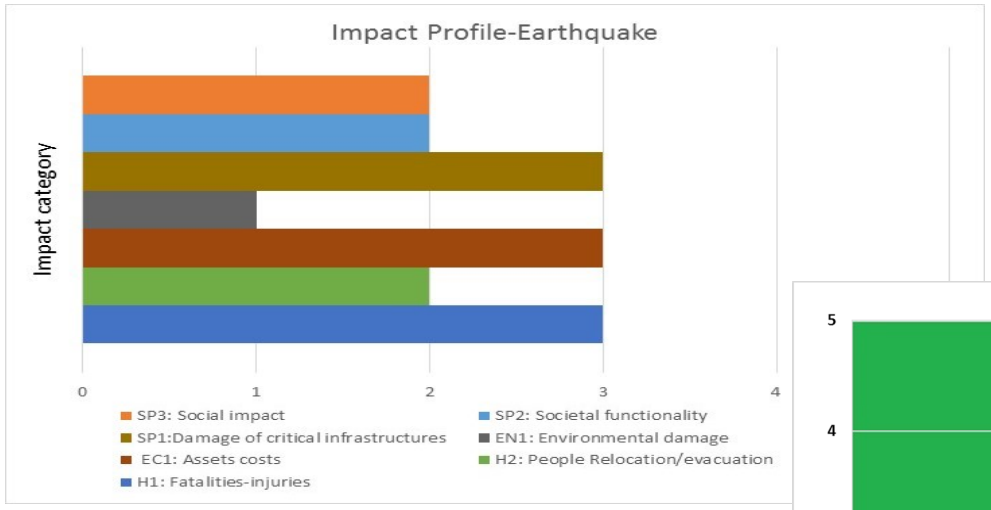
- Earthquake risk study in Cyprus as part of NRA-CY
- Probabilistic event-based risk analysis
- Average annual loss: 116M euro
- Average annual loss ratio: 0.36%
- Masonry & low-to-mid-rise RC buildings with no ERD contribute the most to total loss
- Loss distribution for 10% and 2% poe in 50 years
- Seismic risk scenarios
- Loss maps, collapsed maps
- Casualty modelling, displaced population



NRA RISK MATRIX-consequences

Table 18 Input data of Impact analysis for earthquake										
EARTHQUAKE - Probability of occurrence: 3										
Impact category	Criterion	Unit	Expected impact	Impact value	**1**	**2**	**3**	**4**	**5**	Category sum
HUMAN	**H1**: Fatalities and injuries	number		C→3						
	H2: People Relocation/evacuation	number		B→2						5
ECONOMY	→ **EC1**: Assets costs (€)	Euro		C→3						3
	a)Property damage:	Euro								
	b)Cultural heritage	Euro								
	c)Infrastructure:	Euro								
	d)Disruption of economic activity	Euro								
	e)Other specific cost	Euro								
ENVIRONMENT	**EN1**: Environmental damage	sq km		A→1						1
SOCIAL-POLITICAL	**SP1**:damage critical infrastructures	Number, duration		C→3						
	SP2: everyday life/needs disruption	Number, duration		B→2						
	SP3: social impact	qualitative		B→2						7

NRA RISK MATRIX



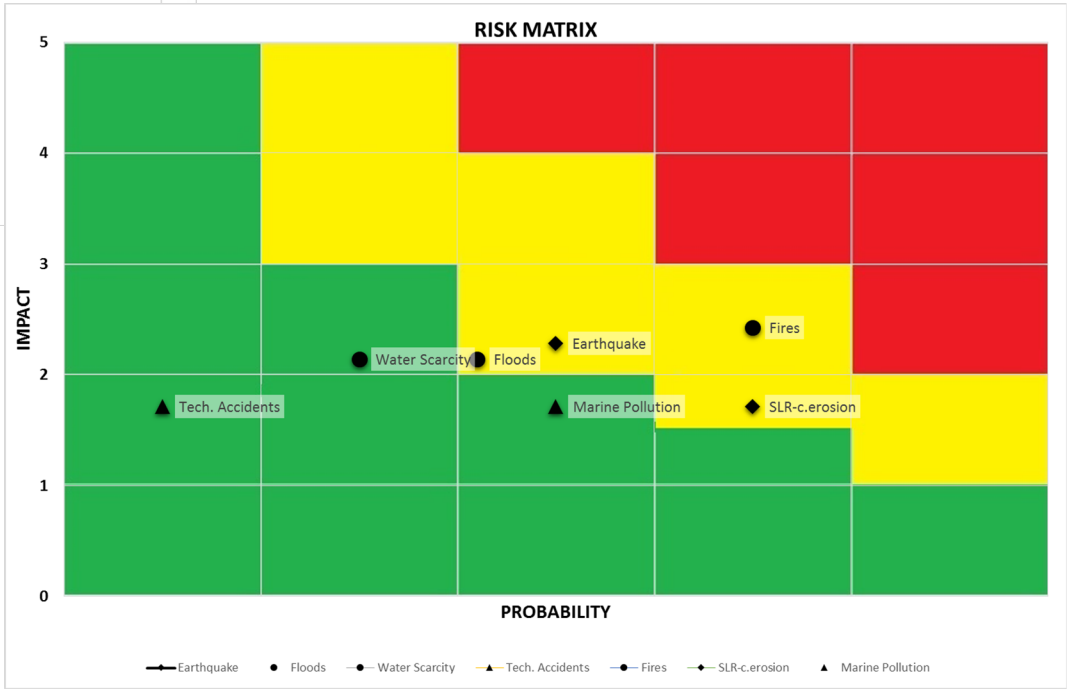


Figure 12.2 Integrated risk matrix for the expected case hazard scenarios

Thank you !