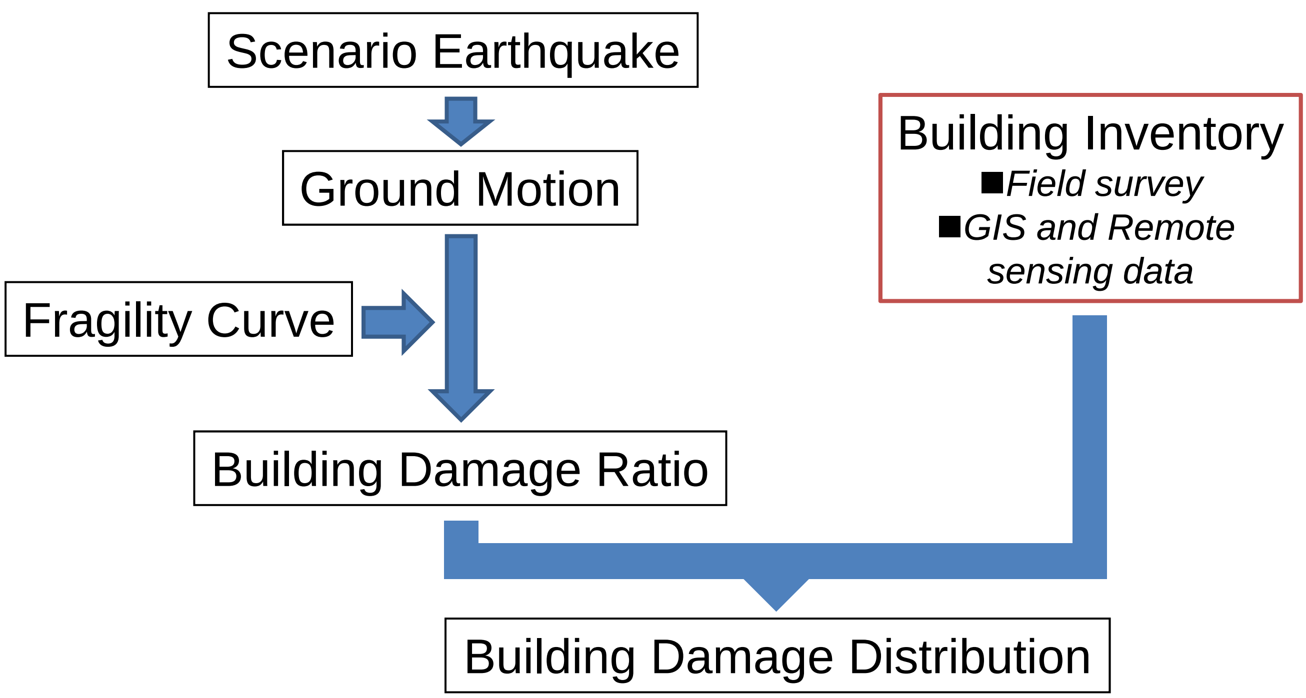
G4 (Damage Assessment)Objectives

- Geospatial dataset construction from satellite imagery (PRISM, Landsat, IKONOS, WV-2, etc.)
- Building inventory construction and vulnerability assessment using spatial information such as satellite image and census data
- Building damage estimation for scenario earthquake based on inventory data
- Methodology development of damage detection using remotely sensed data and transfer to Peruvian institutions

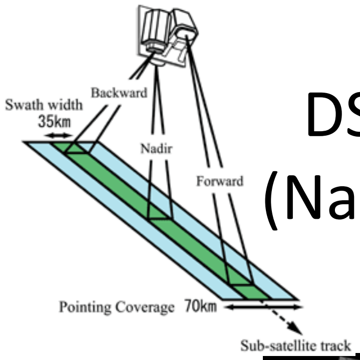
2-2 Landuse

Building Inventory Development for Damage Assessment

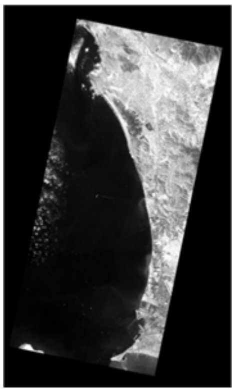
Flow of Building Damage Assessment



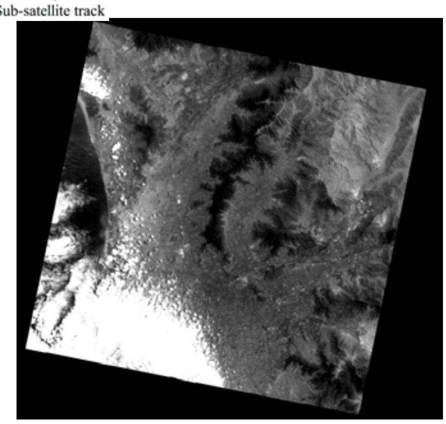
DSM Construction from PRISM Images (Nadir, Forward and Backward Shootings)

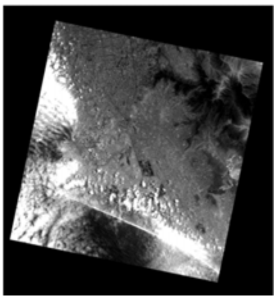


Spatial resolution: 5 m

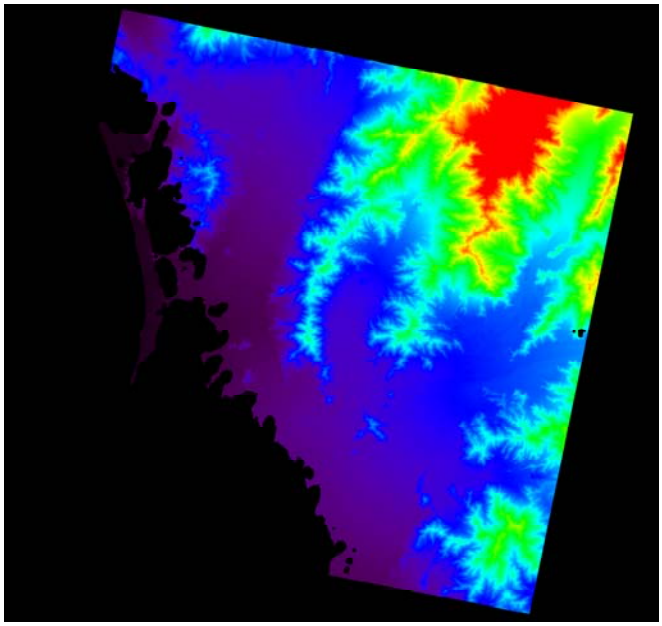


2008/4/14



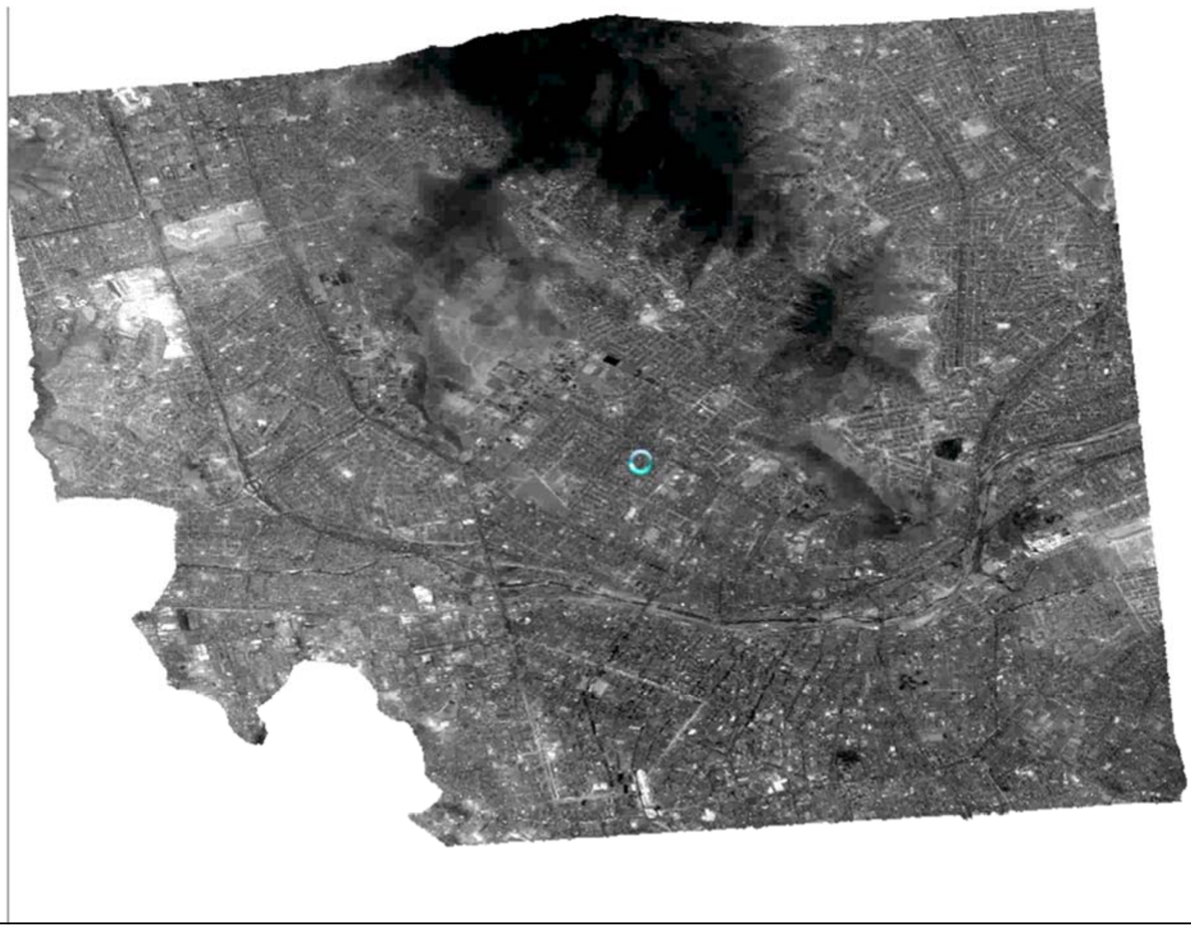


2008/10/15

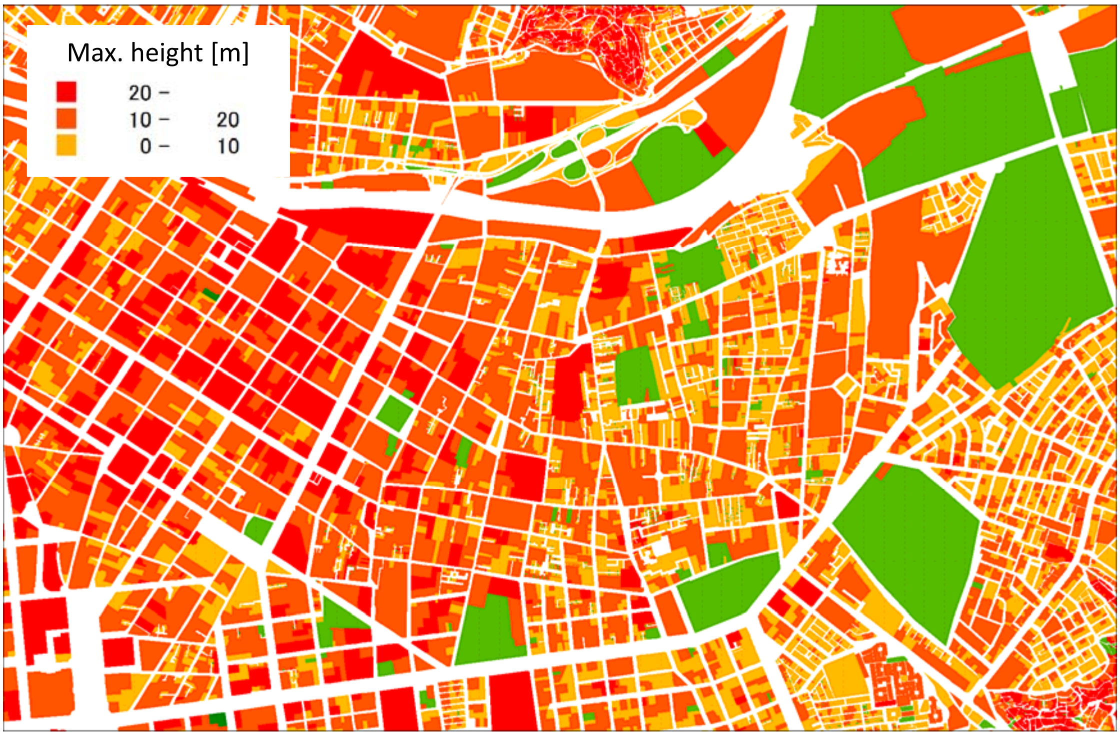


DSM

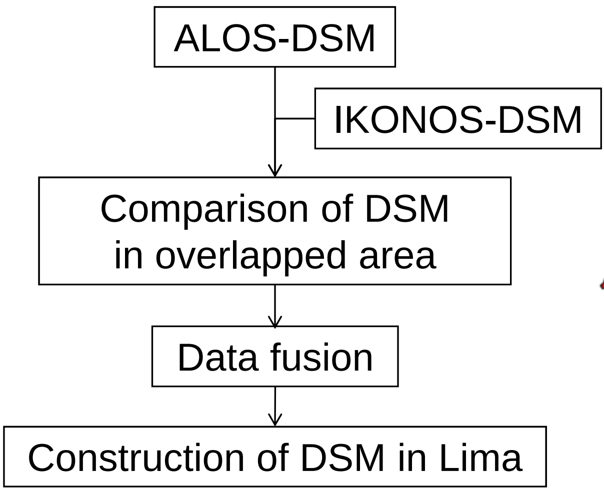
ALOS/PRISM DSM in Downtown Lima

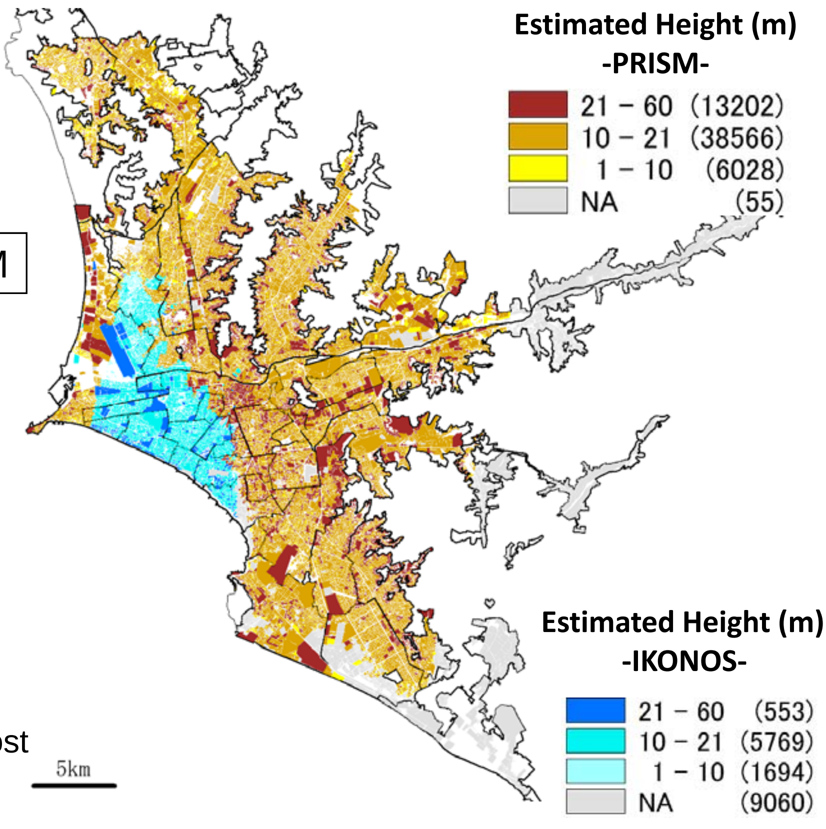


Estimated Building Height at Lot in City Block Using PRISM DSM



Merging DSM by PRISM and IKONOS to Estimate Building Height





Although cloud-cover area is still remained in some parts, DSM in almost all Lima has been obtained.

INEI Census Data（Lima）

2-2 Landuse

Housing Use Type

Detached house (Casa independiente)

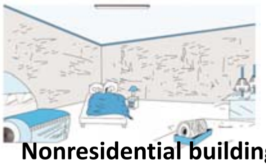
Apartment building (Departamento en edificio)

Cooperative dwelling (Vivienda en quinta)

Cooperative dwelling (Vivienda en casa de vecindad: callejón, solar o corralón)

Small house (Choza o cabaña)

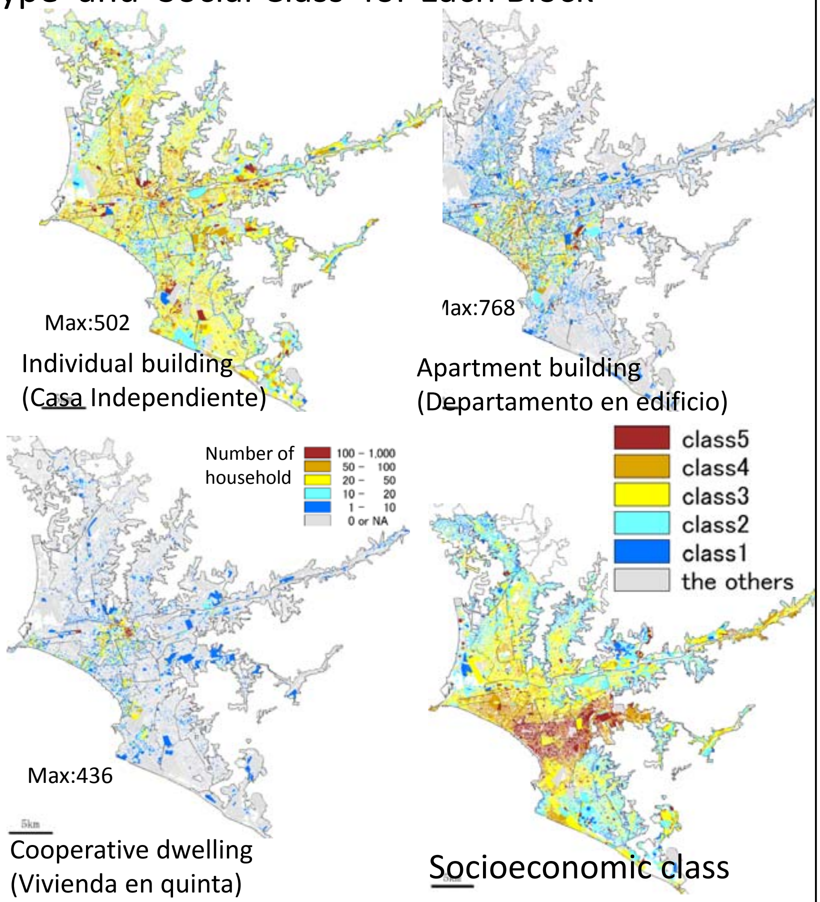
Temporary house (Vivienda improvisada)



Nonresidential building (Local no destinado para habitación humana)

Other (Otro tipo)

Number of Households for Different Housing Use Type and Social Class for Each Block



2-2 Landuse

Housing Use Type

Detached house (Casa independiente)

Apartment building (Departamento en edificio)

Cooperative dwelling (Vivienda en quinta)

Cooperative dwelling (Vivienda en casa de vecindad: callejón, solar o corralón)

Small house (Choza o cabaña)

Temporary house (Vivienda improvisada)

Nonresidential building (Local no destinado para habitación humana)

Other (Otro tipo)

To evaluate seismic performance of building, we need information on building construction type, not housing use type.

Convert

Building Construction Type

A

Adobe etc. (Low-rise)

M1

Non-engineered masonry (Low-rise)

M2

Reinforced or confined masonry with flexible slabs (Low-rise)

M3

M4

Reinforced or confined masonry with rigid slabs
(Low-rise) (Mid-rise)

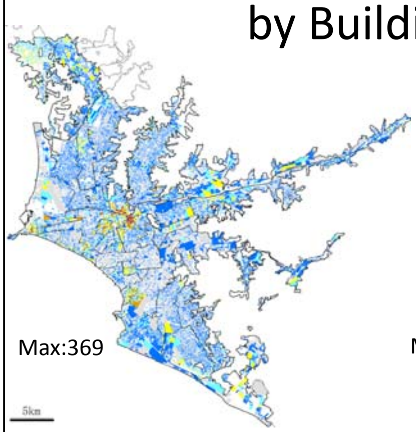
M5

M6

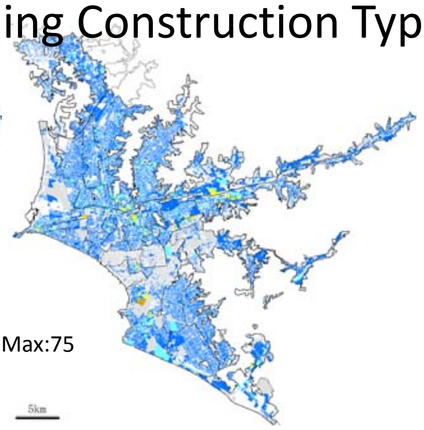
Reinforced concrete frames
(Mid-rise) (High-rise)

Distribution of Estimated Number of Households by Building Construction Type

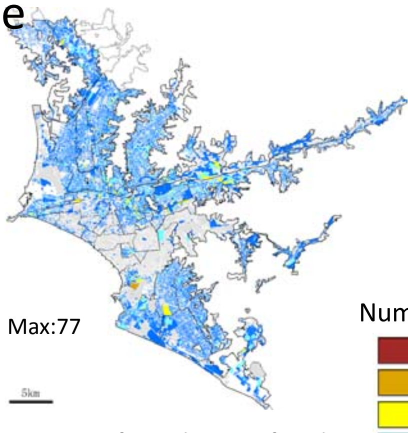
2-2 Landuse



A: Adobe etc. (Low-rise)



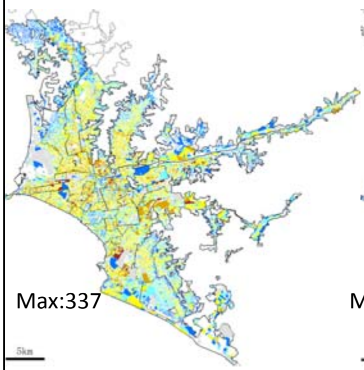
M1: Non-engineered masonry (Low-rise)



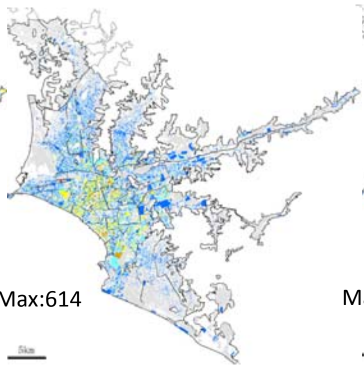
M2: Reinforced or confined masonry with flexible slabs (Low-rise)

Number of household

	100 – 1,000
	50 – 100
	20 – 50
	10 – 20
	1 – 10
	0 or NA

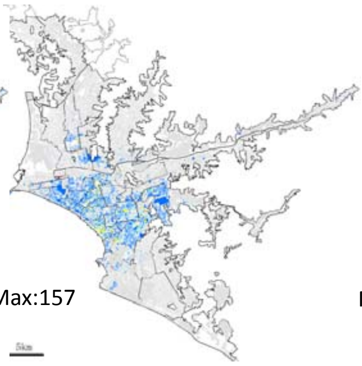


M3: low-rise

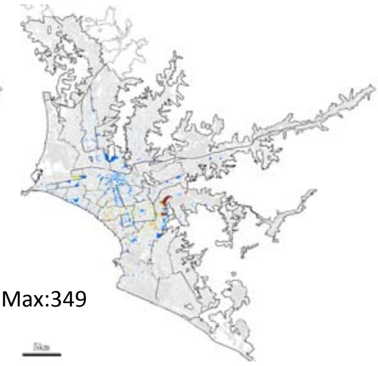


M4: Mid-rise

Reinforced or confined masonry with rigid slabs



M5: Mid-rise



M6: high-rise

Reinforced concrete frames

Distribution of Vulnerable Buildings

2-2 Landuse

Building Construction Type

A

Adobe etc. (Low-rise)

M1

Non-engineered masonry (Low-rise)

M2

Reinforced or confined masonry with flexible slabs (Low-rise)

M3

M4

Reinforced or confined masonry with rigid slabs
(Low-rise) (Mid-rise)

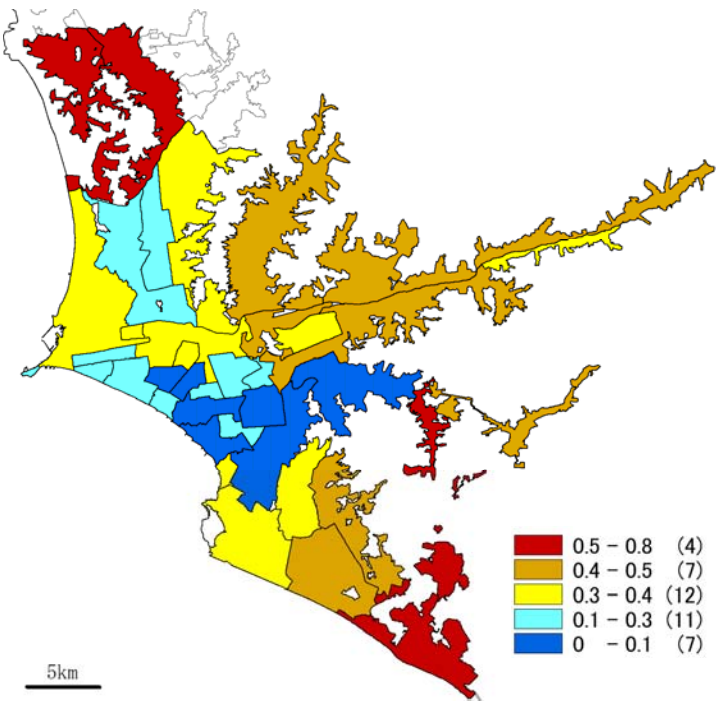
M5

M6

Reinforced concrete frames
(Mid-rise) (High-rise)

Total number of households in Lima: 1,840,000

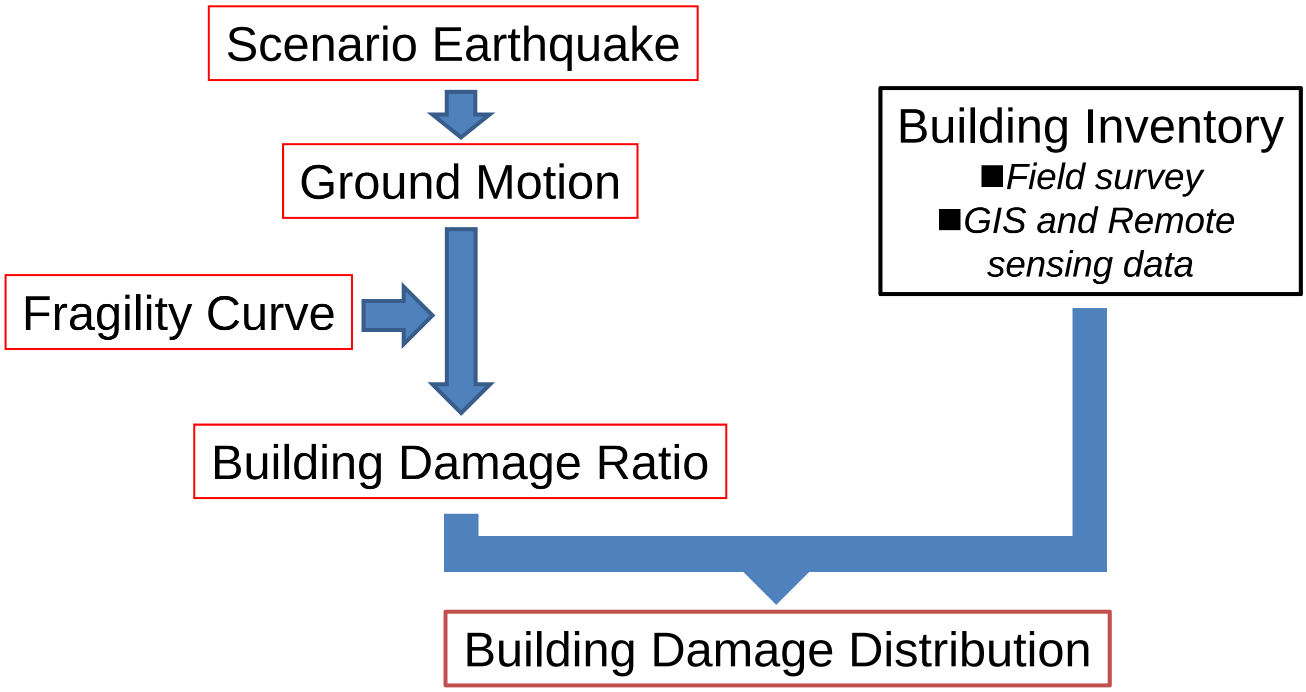
- Adobe etc: 290,000 (A)
- Low earthquake-resistant masonry: 370,000 (M1+M2)
- High earthquake-resistant masonry: 1,100,000 (M3+M4)
- RC building: 80,000 (M5+M6)



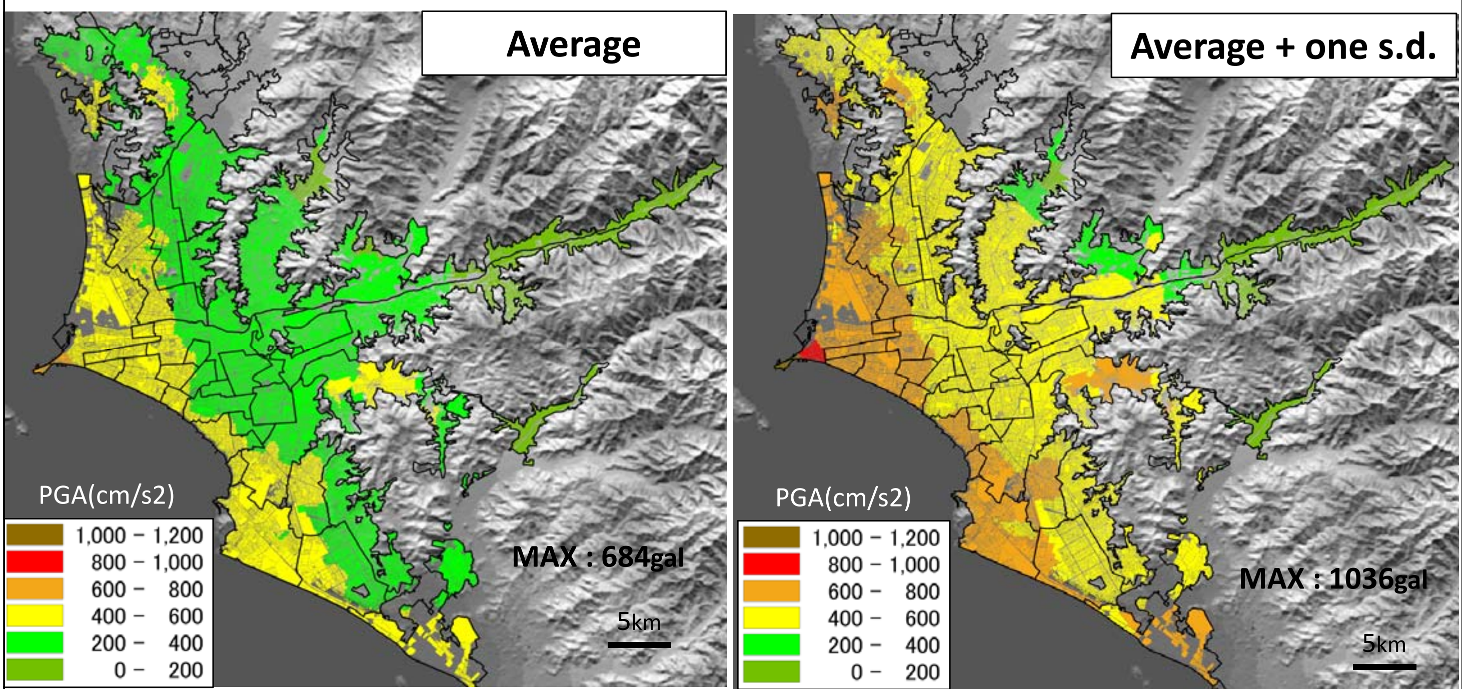
Ratio of Low Earthquake-resistant Building (A+M1+M2)/ALL

Damage Assessment of Scenario Earthquake

Flow of Building Damage Assessment



Ground Motion (PGA Map)

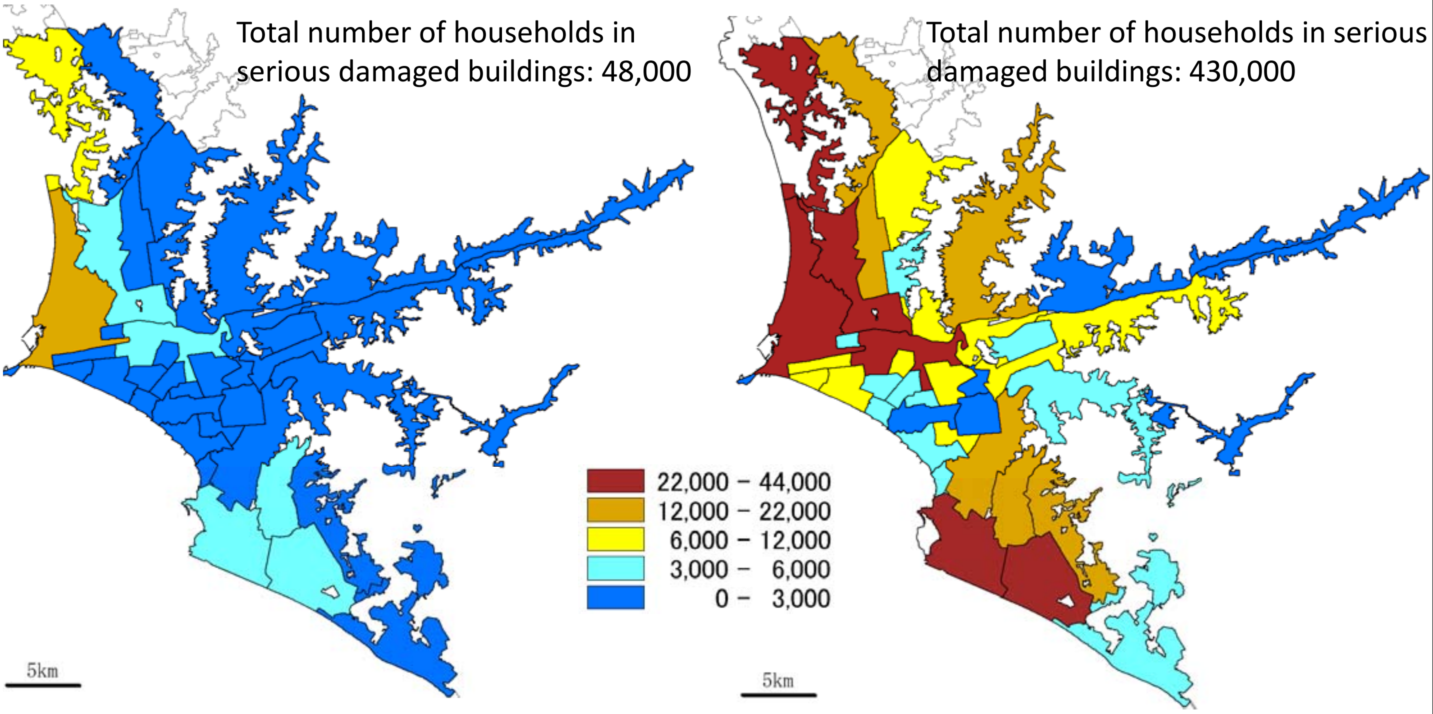


Damage Estimation

Total number of households in Lima: 1,840,000

Total number of households in serious damaged buildings: 48,000

Total number of households in serious damaged buildings: 430,000

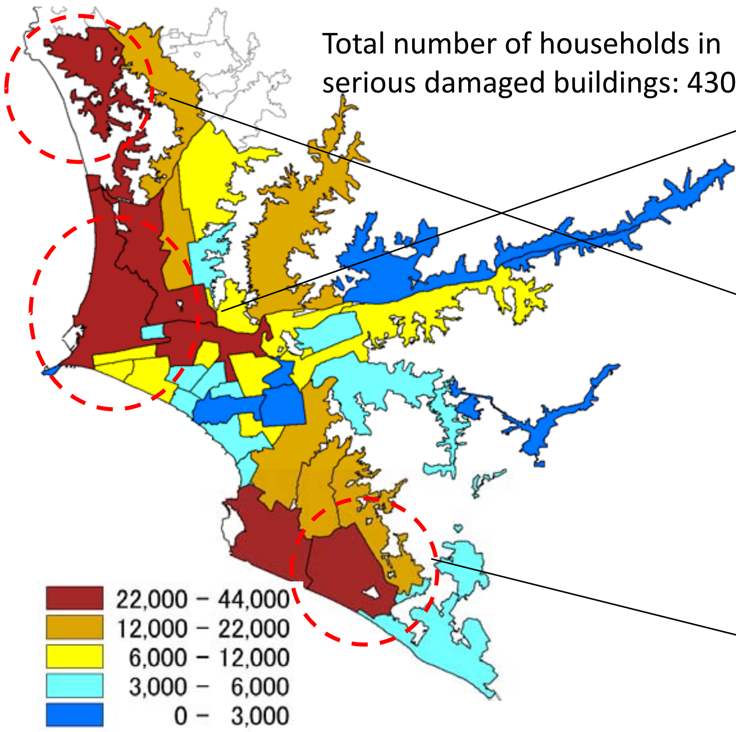


PGA (Average)

PGA (Average + one s.d.)

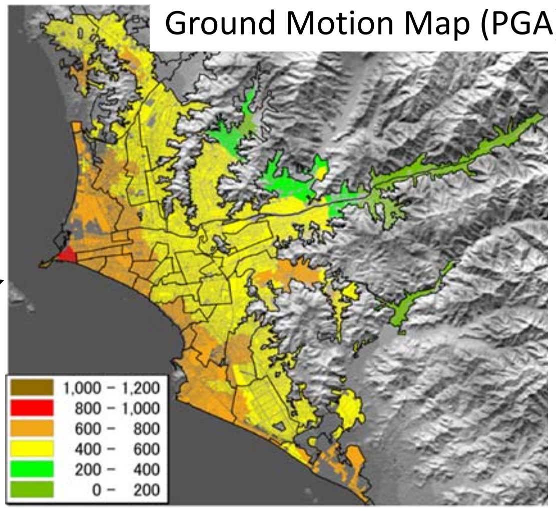
Damage Estimation

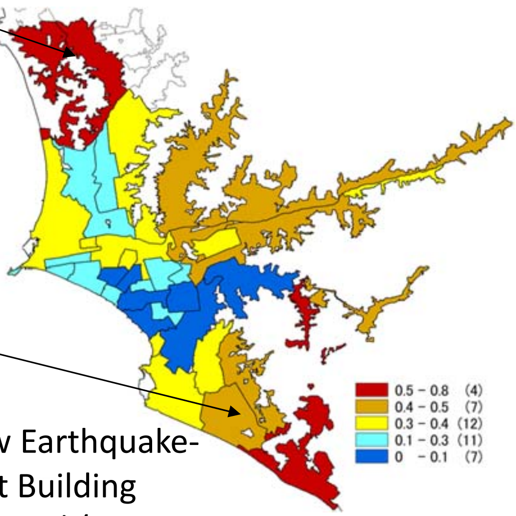
Total number of households in serious damaged buildings: 430,000



PGA (Average + one s.d.)

Ground Motion Map (PGA)





Ratio of Low Earthquake-resistant Building (A+M1+M2)/ALL

Example Cases of Seismic Retrofit

Case 1

Adobe etc. (A)

290,000 Households

retrofitting

Non-engineered masonry (M1) or
Reinforced or confined
masonry with flexible slabs (M2)

Case 2

Adobe etc. (A)

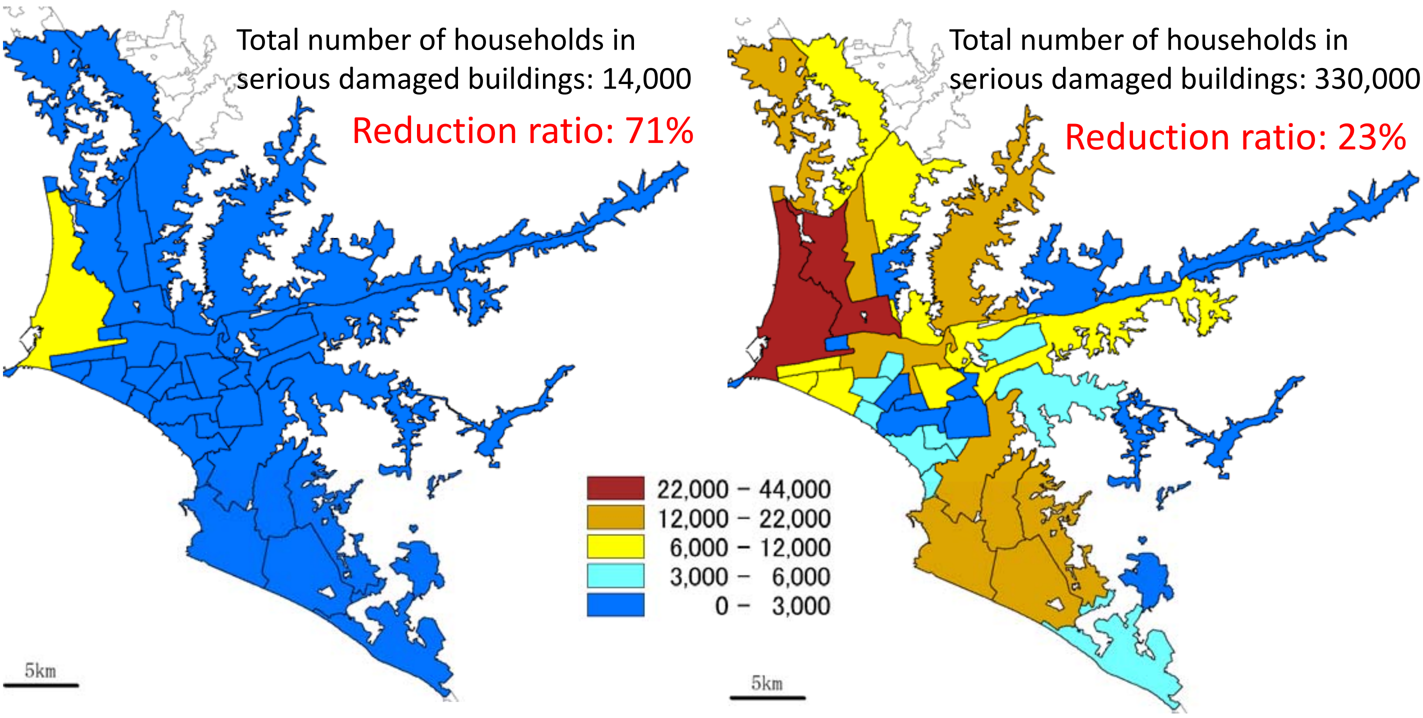
Non-engineered masonry (M1) or
Reinforced or confined
masonry with flexible slabs (M2)

560,000 Households

retrofitting

Reinforced or confined masonry
with rigid slabs (M3, M4)

Damage Estimation
- after retrofitting (Case 1) -



Total number of households in serious damaged buildings: 14,000

Reduction ratio: 71%

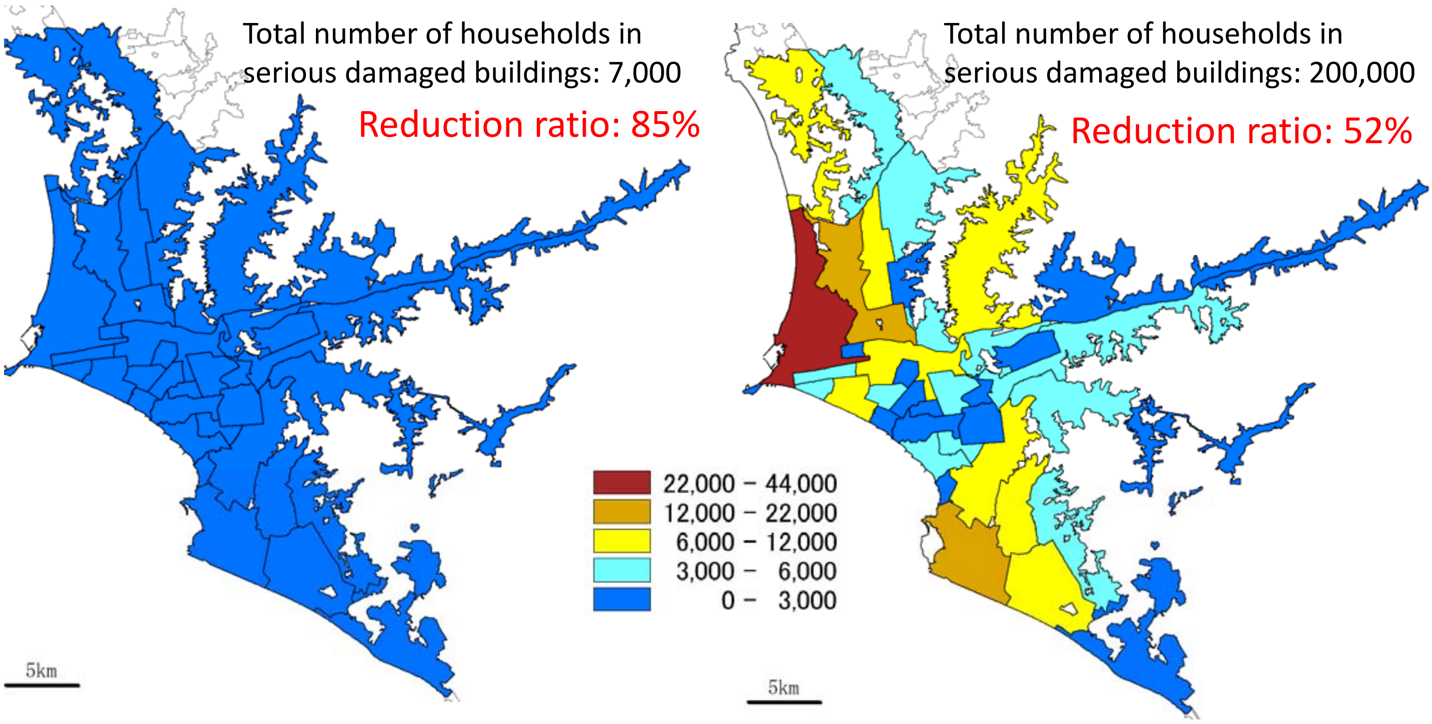
PGA (Average)

Total number of households in serious damaged buildings: 330,000

Reduction ratio: 23%

PGA (Average + one s.d.)

Damage Estimation
- after retrofitting (Case 2) -

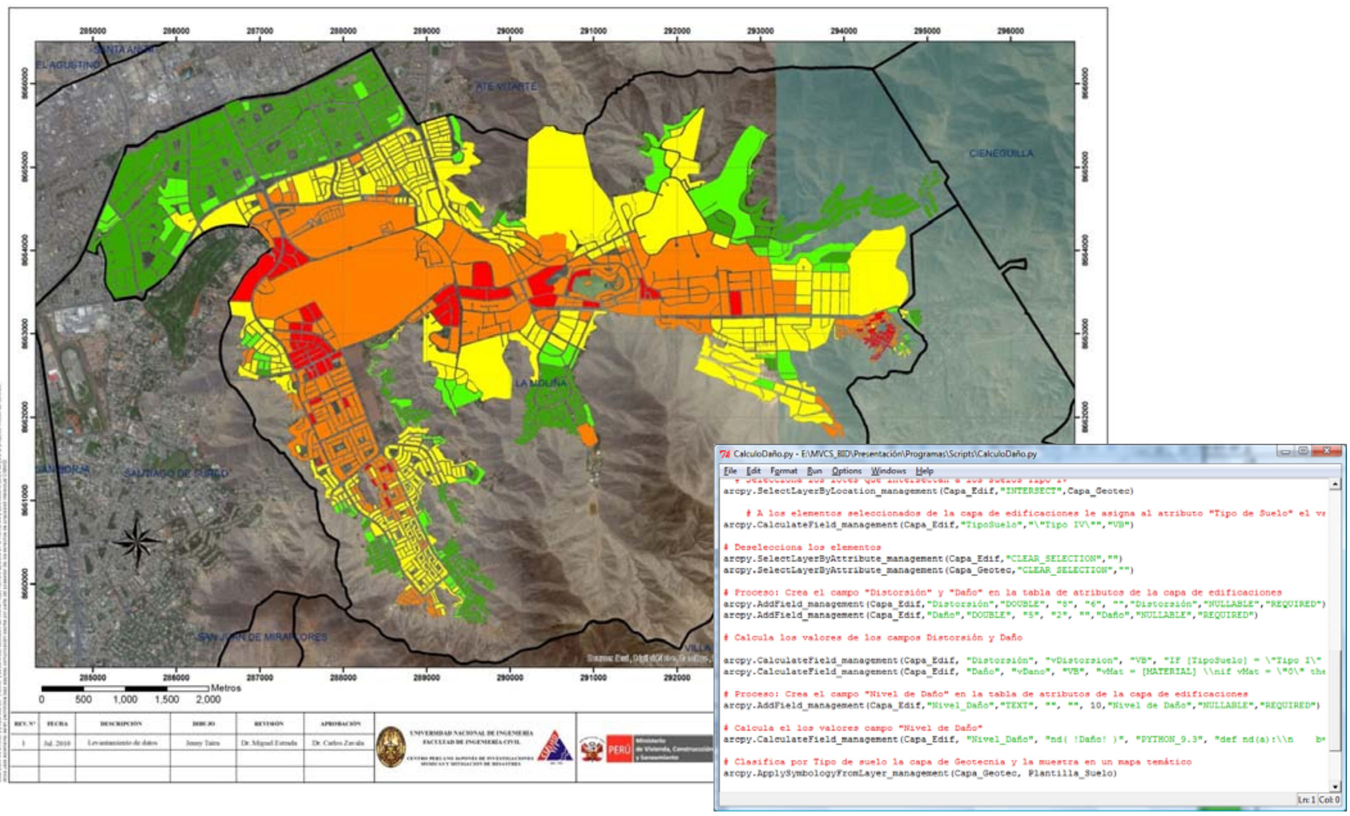


PGA (Average)

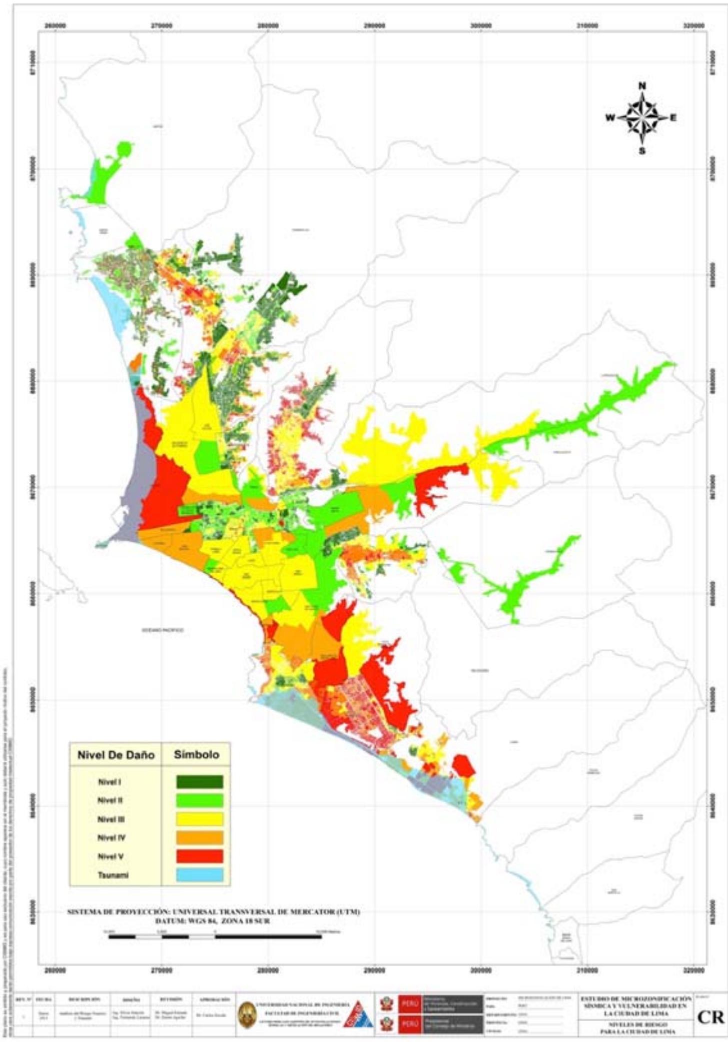
PGA (Average + one s.d.)

5-1 Damage

Development of GIS Tools to Estimate Repair Cost of Damage



Distribution of Repair Cost



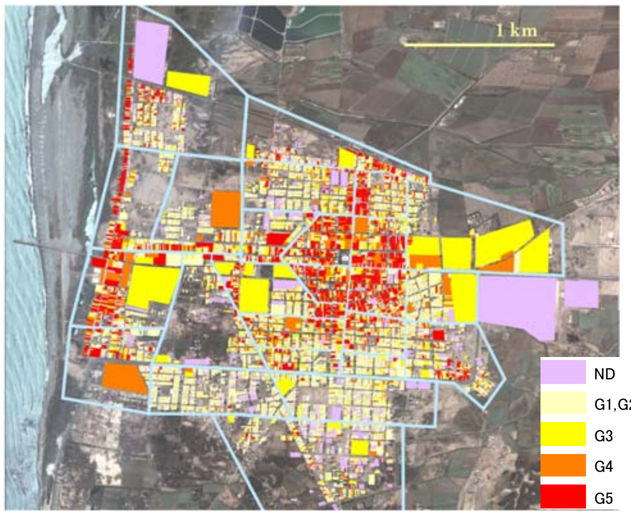
Detection of Damaged Buildings using QuickBird Images following the 2007 Pisco EQ.

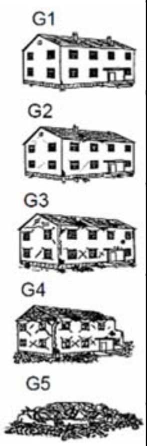
Field photo
SEP 12, 2007
(27 days after)

Pre-event
JAN 3, 2007

Post-event
AUG 27, 2007
(12 days after)

Result of visual damage inspection

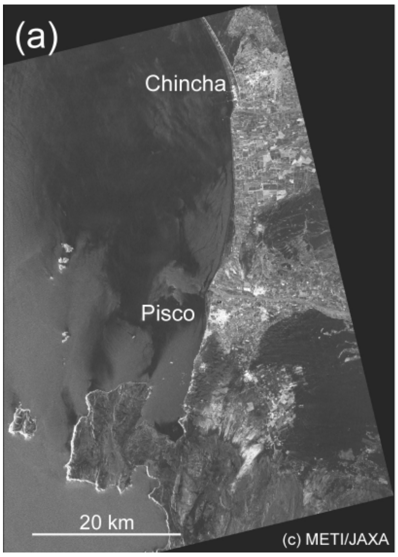




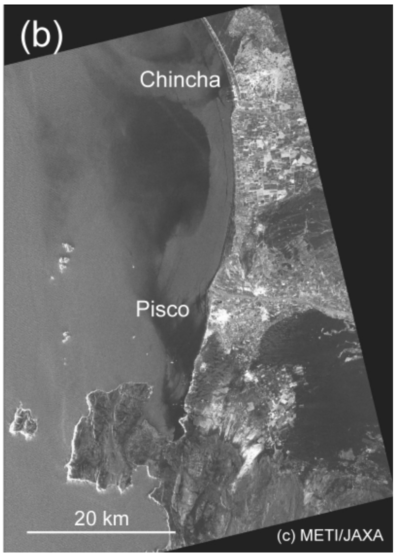
Classification of visual interpretation: By EMS1998		Classification of field survey: By CISMID
Grade1	Fall of small pieces only	SIN DAÑO (**No damage**)
Grade2	Moderate non-structural damage	LEVE (**Slight damage**)
Grade3	Large cracks, non-structural damage	SEVERO (**moderately-Severe**)
Grade4	Serious failure of walls, partial failure of roofs and floors	GRAVE (**Serious**)
Grade5	Total collapse	

	No damage or slight	Moderate	Serious or collapse	sum	User's accuracy
G1,G2	4900	735	725	6360	77.0%
G3	714	266	240	1220	21.8%
G4,G5	570	501	2175	3246	67.0%
sum	6184	1502	3140	10826	
Producer's accuracy	79.2%	17.7%	69.3%	Overall accuracy =67.7%	

Synthetic Aperture Radar (SAR) Observation for Earthquake Damage Detection

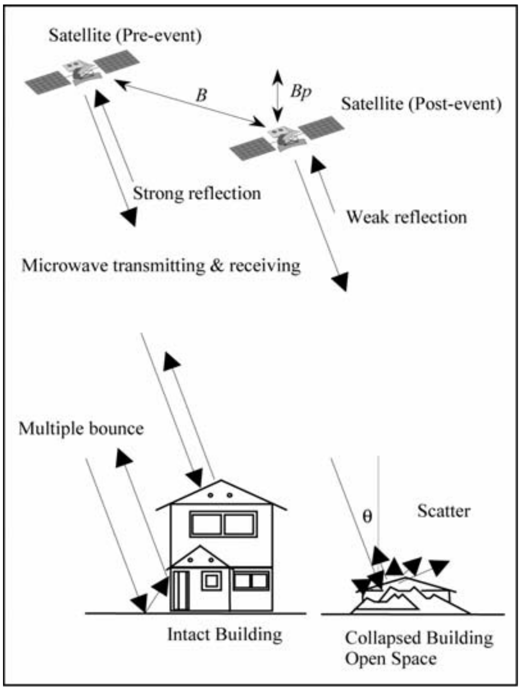


(a) 2007/7/12 [before Earthq.]



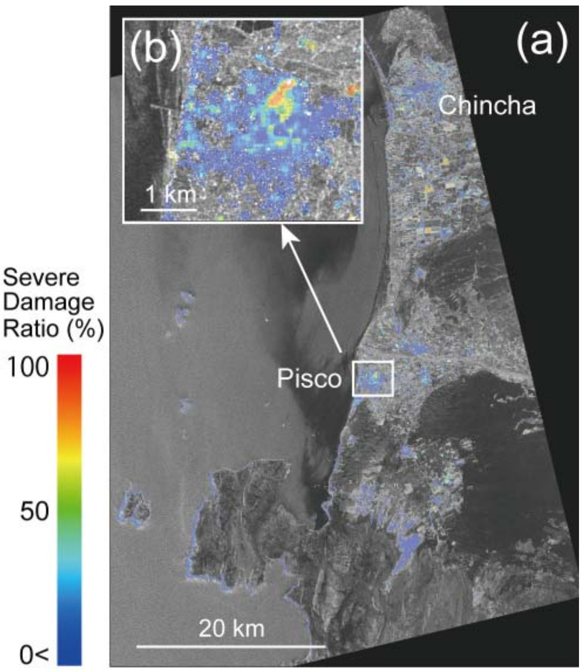
(b) 2007/8/27 [after Earthq.]

ALOS/PALSAR Images

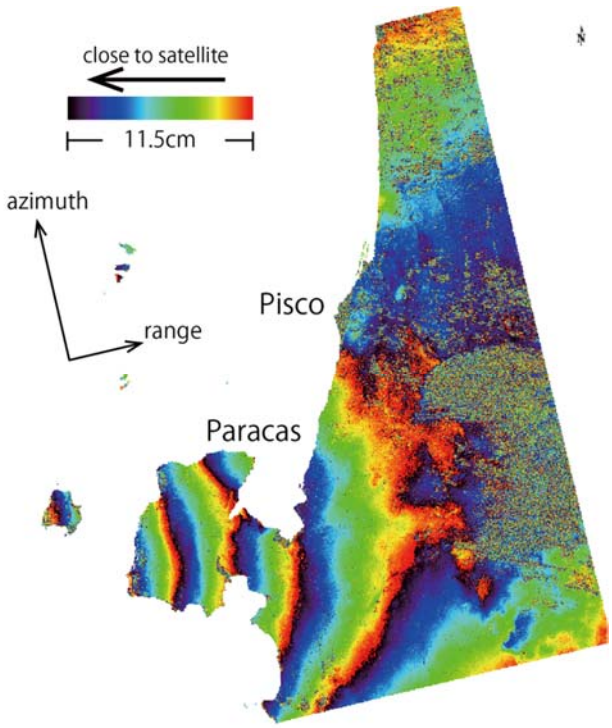


Schematic Figure of Backscattering Characteristics of Buildings

Estimated Damage and Displacement due to the 2007 Pisco Earthquake



Severe damage ratio estimated using pre- and post-earthquake PALSAR images and seismic Intensity information



Co-seismic surface deformation calculated by interferometric SAR technique using pre- and post-earthquake PALSAR images

Conclusions

For estimating earthquake damage in Lima, Peru, we have proposed a simple method for generating building inventory data using GIS data from census, satellite imagery, and data from field surveys.

By calculating the damage probability of buildings based on fragility curves for the input ground motion of an anticipated earthquake and multiplying probability by created building inventory data, we estimated the number and distribution of households in buildings that could be seriously damaged.

Conclusions

Results showed that the risk of damage was higher in districts close to the coastal area and districts containing many low earthquake-resistant buildings.

The feasibility of seismic retrofitting was verified and it was also shown that the number of households in buildings that would be seriously damaged could be reduced by half if adobe and low earthquake-resistant masonry buildings could be renovated into high earthquake-resistant buildings such as reinforced or confined masonry with rigid slabs.