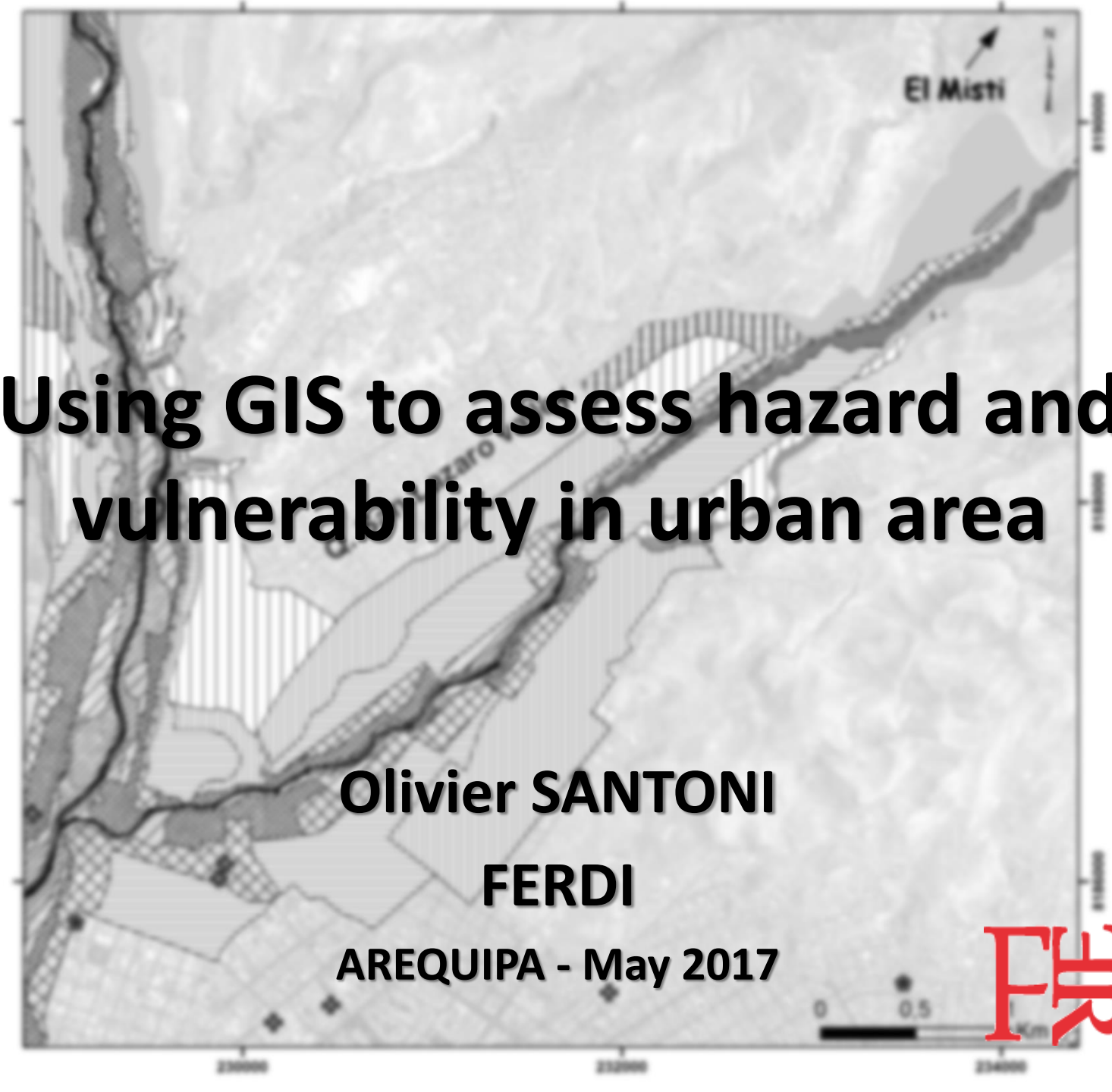


Using GIS to assess hazard and vulnerability in urban area

Olivier SANTONI

FERDI

AREQUIPA - May 2017

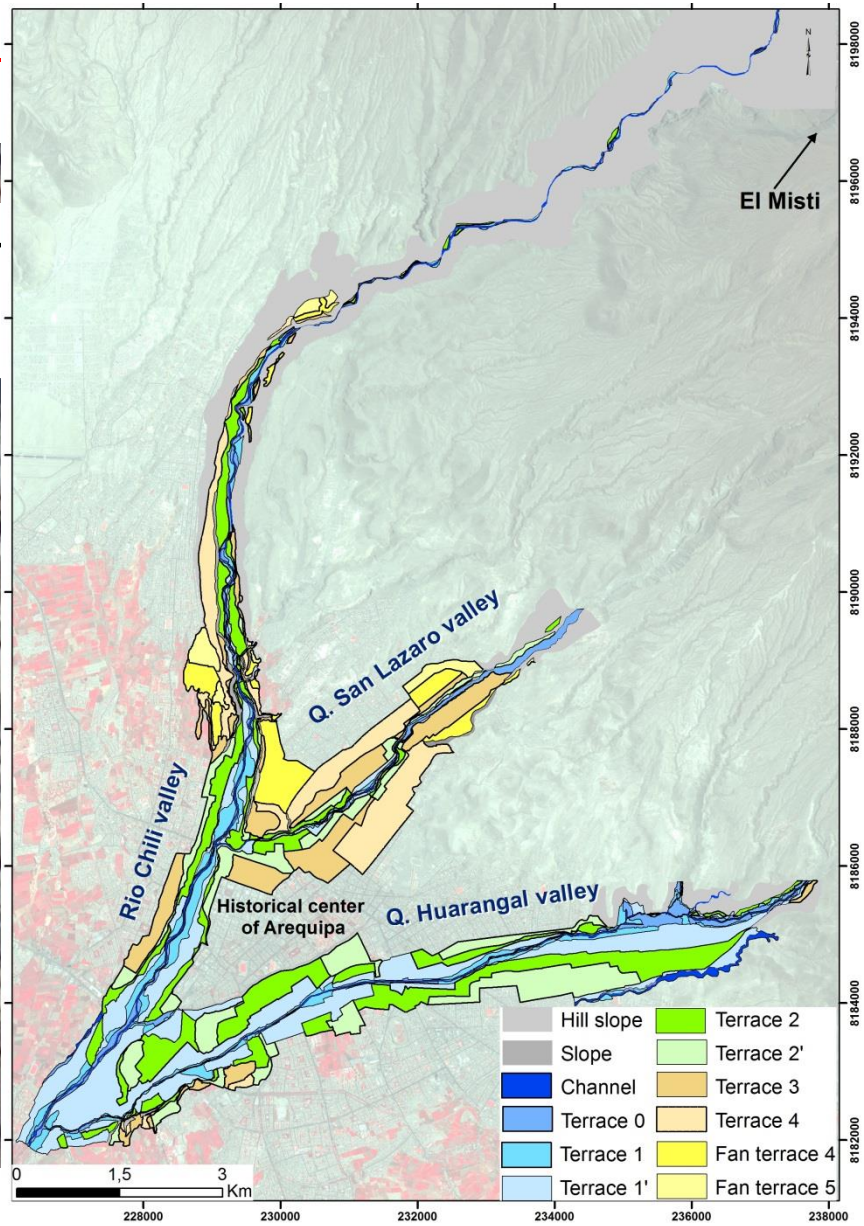
Risk assessment

- Hazard mapping
- Vulnerability mapping at city block scale
  - Population vulnerability
  - Physical vulnerability
- Complete building inventory using satellite imagery

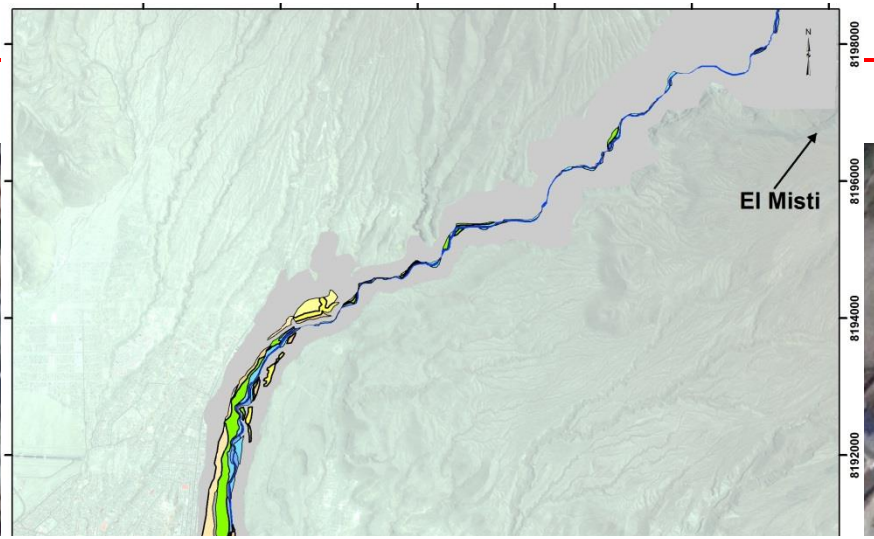
Determining alluvial terraces

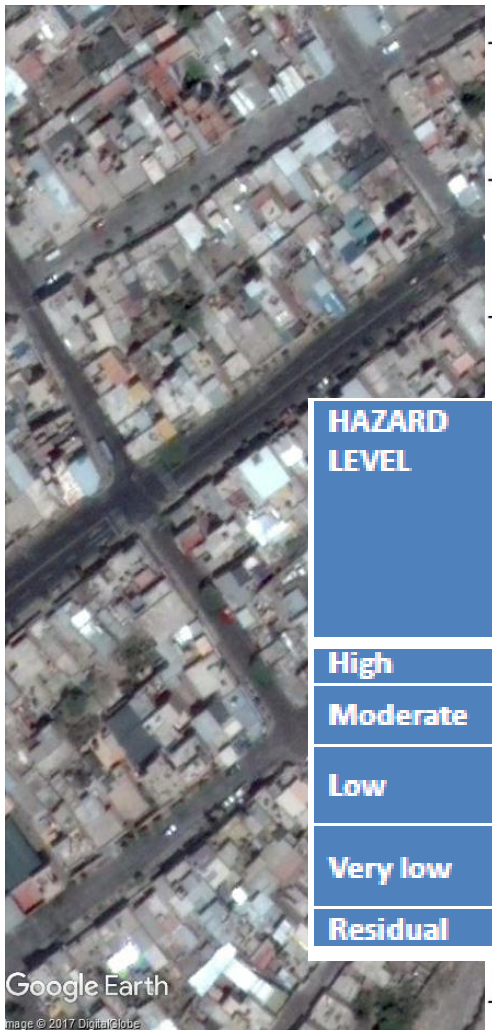
Determining alluvial terraces

Google Earth im
Field data



Determining alluvial terraces

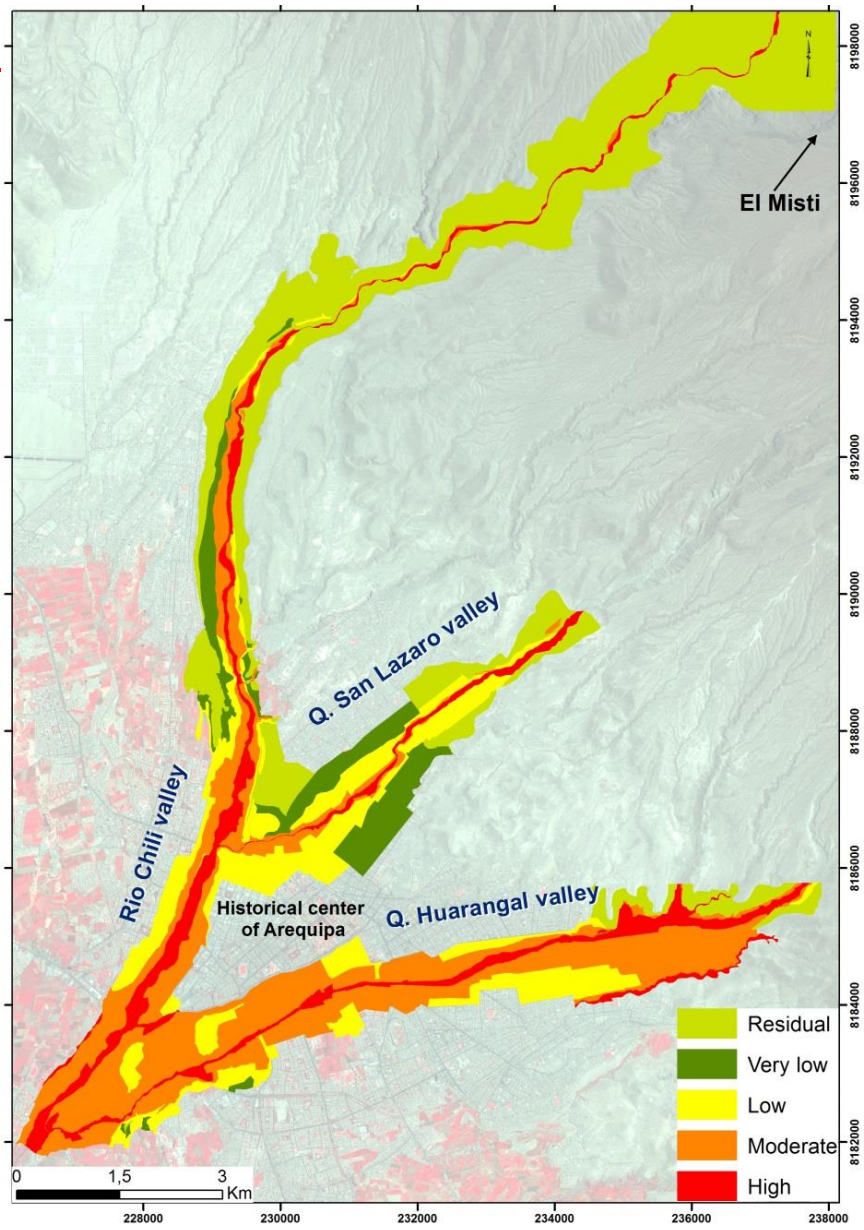




HAZARD LEVEL	GIS grade	TERRACES	FLASH FLOODS		LAHARS (hyperconcentrated streamflows and debris flows)	
		Number	Return period	Discharge (m^3/s)	Return period	Discharge (m^3/s)
High	5	T0 + T1	< 1	5 - 10	10-50	10-50
Moderate	4	T1'+ T2	1-4	>10 – 50	50-100	50-100
Low	3	T2' + T3	4—40	50 - 100	100-260	>100-1000
Very low	2	T4	➢ 40	>100 - 1000	>260	>1000 - 10000
Residual	1	Above T4	/	/	/	/

Determining alluvial terraces

5 flow hazard intensities based on discharge and return period



Socio-economic vulnerability

Calculation of weighted distances of every city block to 4 relief infrastructure taking account the road types, presence of bridges and rivers.

Road type	Criteria	Weigh coefficient
Type 1	Major roads.	1m = 1
Type 2	Good, large and paved streets.	1m = 1.5
Type 3	Half paved and half dirt (or gravel road). Well graded and maintained.	1m = 1.7
Type 4	Gravel road or dirt road, sometimes with slope. Badly or even not graded.	1m = 1.9
Type 5	Out of the city, connection with remote houses.	1m = 2.1
Bridges		1m = 3
Rivers		Cannot be crossed without bridges

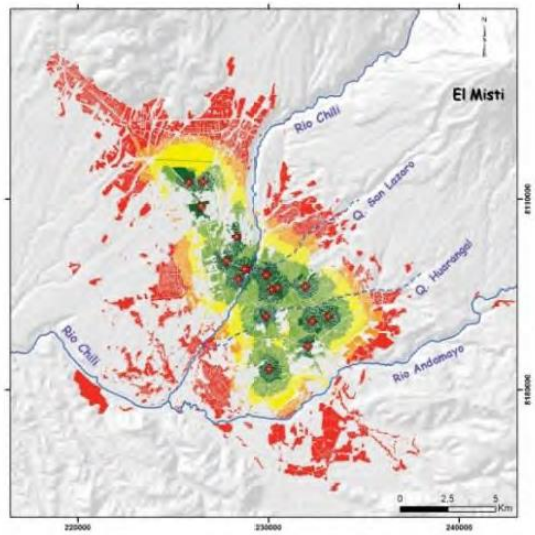
Socio-economic vulnerability

Calculation of weighted distances of every city block to 4 rescue infrastructures taking account the roads types, présences of bridges and rivers.

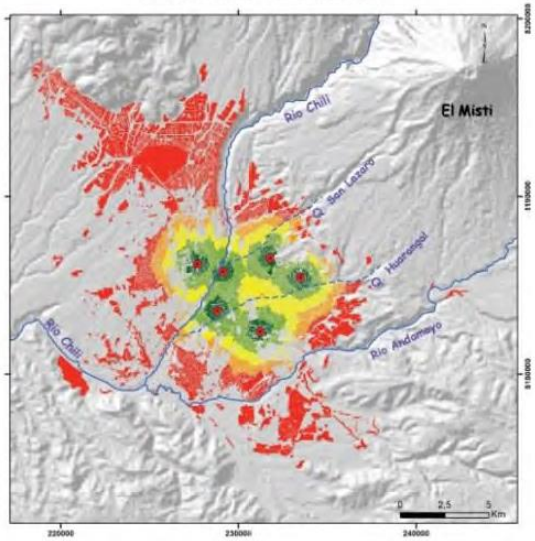
Distance to : weighted by the quality of cross roads			
Safe areas (10A)	Fire stations (10B)	Water tanks (10C)	Hospitals (10D)
0 to 250 m	0 to 1000 m	0 to 500 m	0 to 1000 m
251 to 500 m	1001 to 2000 m	501 to 1000 m	1001 to 2000 m
501 to 750 m	2001 to 3000 m	1001 to 1500 m	2001 to 3000 m
751 to 1000m	3001 to 4000 m	1501 to 2000 m	3001 to 4000 m
More than 1001 m	More than 4001 m	More than 2001 m	More than 4001 m

Safe area
Fire station
Water tank
Hospital
Permanent river
Dry stream valley

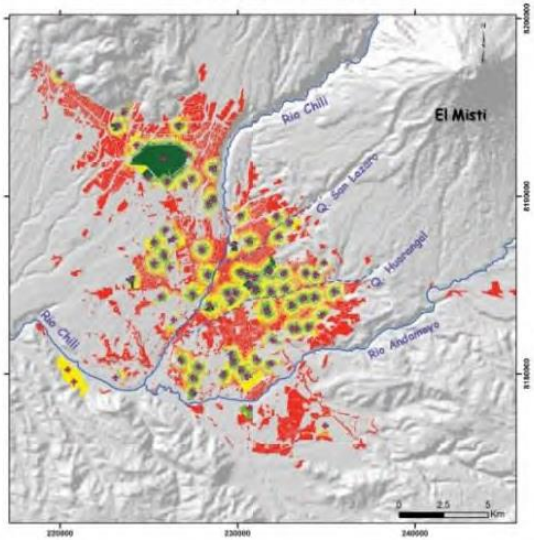
A. Distance to hospitals



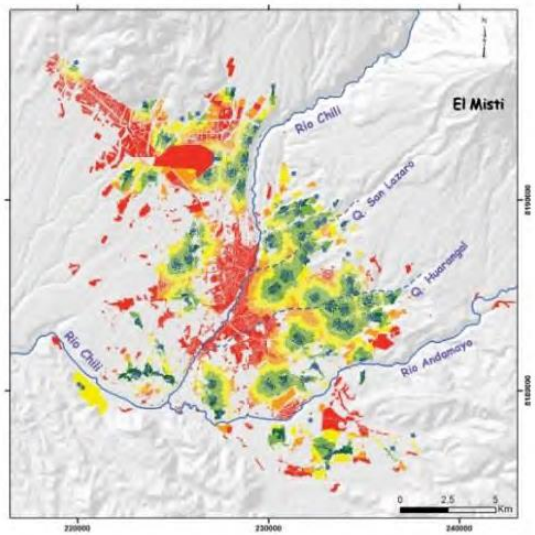
B. Distance to fire stations



C. Distance 'safe' areas



D. Distance water tanks



Isolation index

Name	Data used	Sources	Calculation
Distance to hospitals (DH)	Public and large private hospitals	Google Maps™ (2011), Gobierno Regional de Arequipa (2007), Municipalidad Provincial de Arequipa (2002)	From 1 to 5: A class each 1000 m. Elaborated with ArcGIS's Spatial Analyst using a road cost raster
Distance to fire stations (DFS)	Fire stations	Cuerpo General de Bomberos Voluntarios del Perú (2012)	From 1 to 5: A class each 1000 m. Elaborated with ArcGIS's Spatial Analyst using a road cost raster
Distance to safety areas (DSA)	Stadiums and car parks, surface >3500m²	Google Earth Pro™ (2011)	From 1 to 5: A class each 250 m. Elaborated with ArcGIS's Spatial Analyst using a road cost raster
Distance to water tanks (DWT)	Water tanks	Google Earth Pro™ (2011)	From 1 to 5: A class each 500 m. Elaborated with ArcGIS's Spatial Analyst using a road cost raster
Isolation index (II)			From 1 (low isolation= short distance) to 5 (high isolation= long distance). Multiple criteria analysis: - Vital facility: weighting factor 1 - Other facility: weighting factor 0.5 Formula: II = (DH+DFS+DSA+1/2xDWT)/3.5

Isolation index

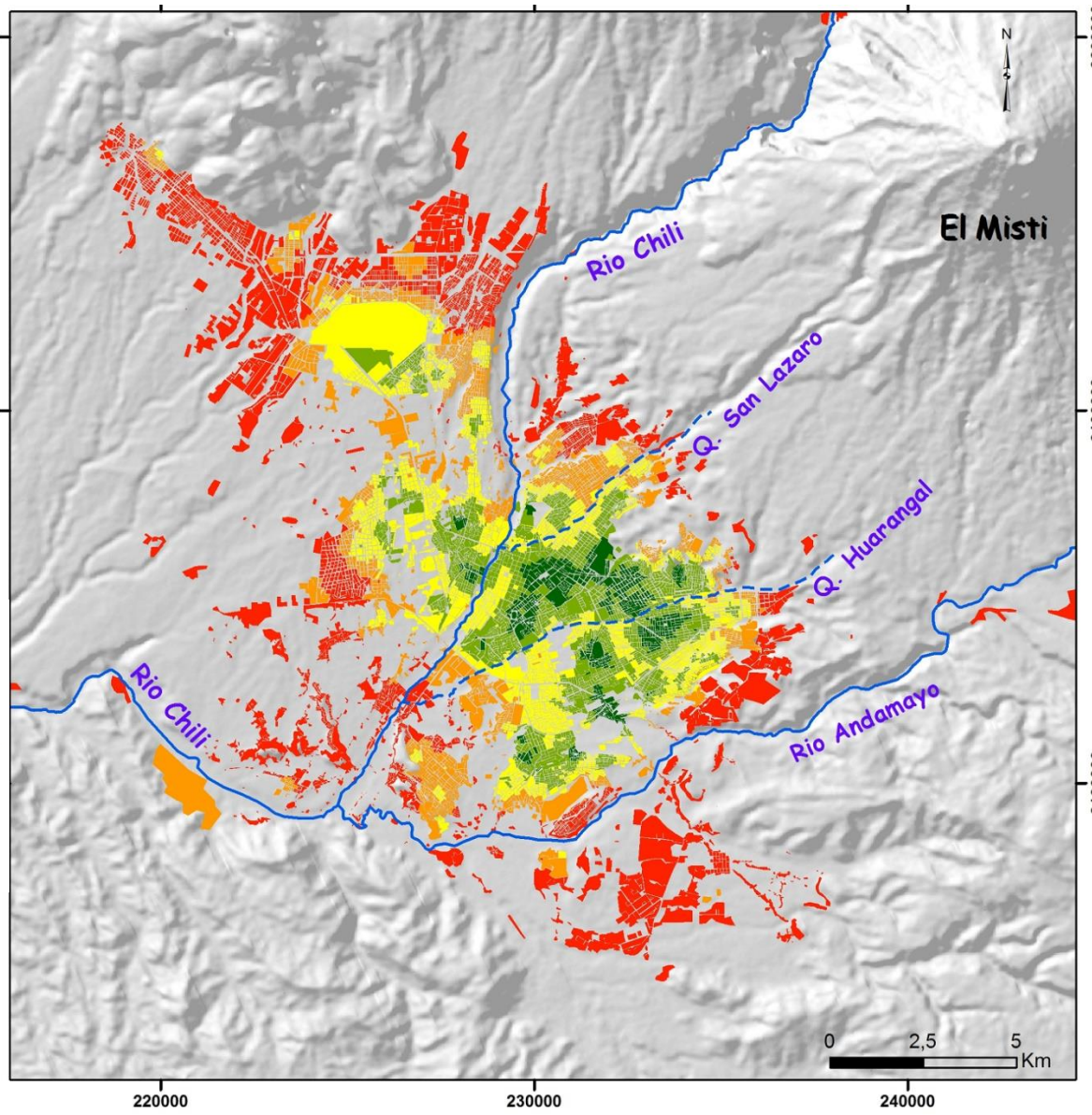
Name	Data used	
Distance to hospitals (DH)	Public and large private hospitals	Google Map Gobierno Re (2007), Municipalida Arequipa (20
Distance to fire stations (DFS)	Fire stations	Cuerpo Gene Voluntarios
Distance to safety areas (DSA)	Stadiums and car parks, surface >3500m²	Google Earth

Isolation index (no unit)

1.2 Low
2
2.8
3.5
4.3
5 High

Permanent river

Dry stream valley

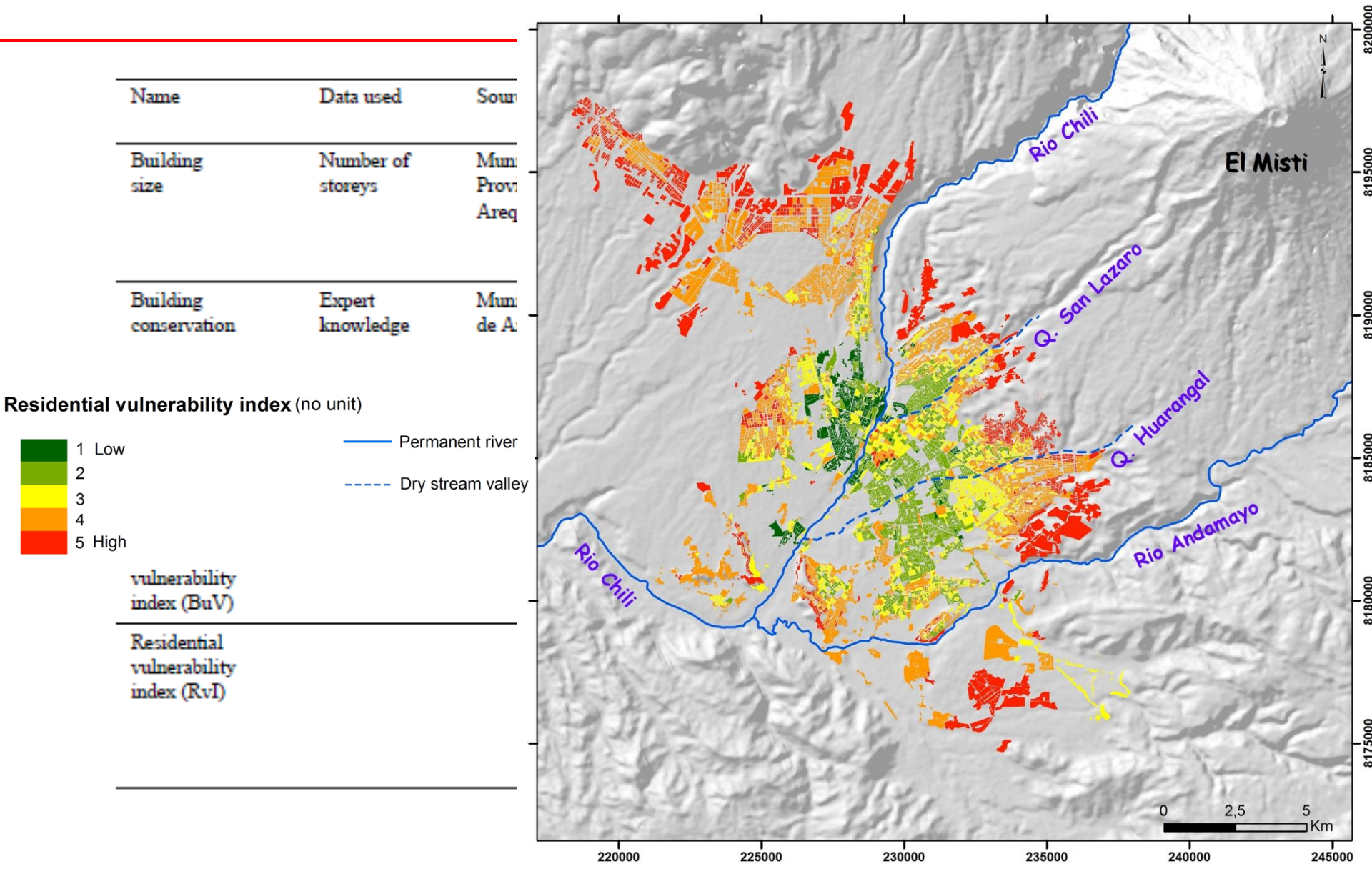


Residential vulnerability index

Name	Data used	Sources	Calculation	Scale of observation
Building size	Number of storeys	Municipalidad Provincial de Arequipa (2002)	Ranked from 1 to 4: 4 storeys and more = 1 3 storeys = 2 2 storeys = 3 1 storey = 4	City block
Building conservation	Expert knowledge	Municipalidad Provincial de Arequipa (2002)	Ranked from 1 to 3: Good maintenance = 1 Medium maintenance = 2 Bad maintenance = 3	City block
Population density	Census	Municipalidad Provincial de Arequipa (2002)	Ranked from 1 to 4: High = 1 Medium = 2 Low = 3 Very low = 4	City block
Building vulnerability index (BuV)			BuV: Building size X Building quality of construction X Population density	City block
Residential vulnerability index (RvI)			Index from 1 to 5: RvI=1 if BuV=1 to 3 RvI=2 if BuV=4 to 6 RvI=3 if BuV=7 to 12 RvI=4 if BuV=13 to 24 RvI=5 if BuV=25 to 48	City block

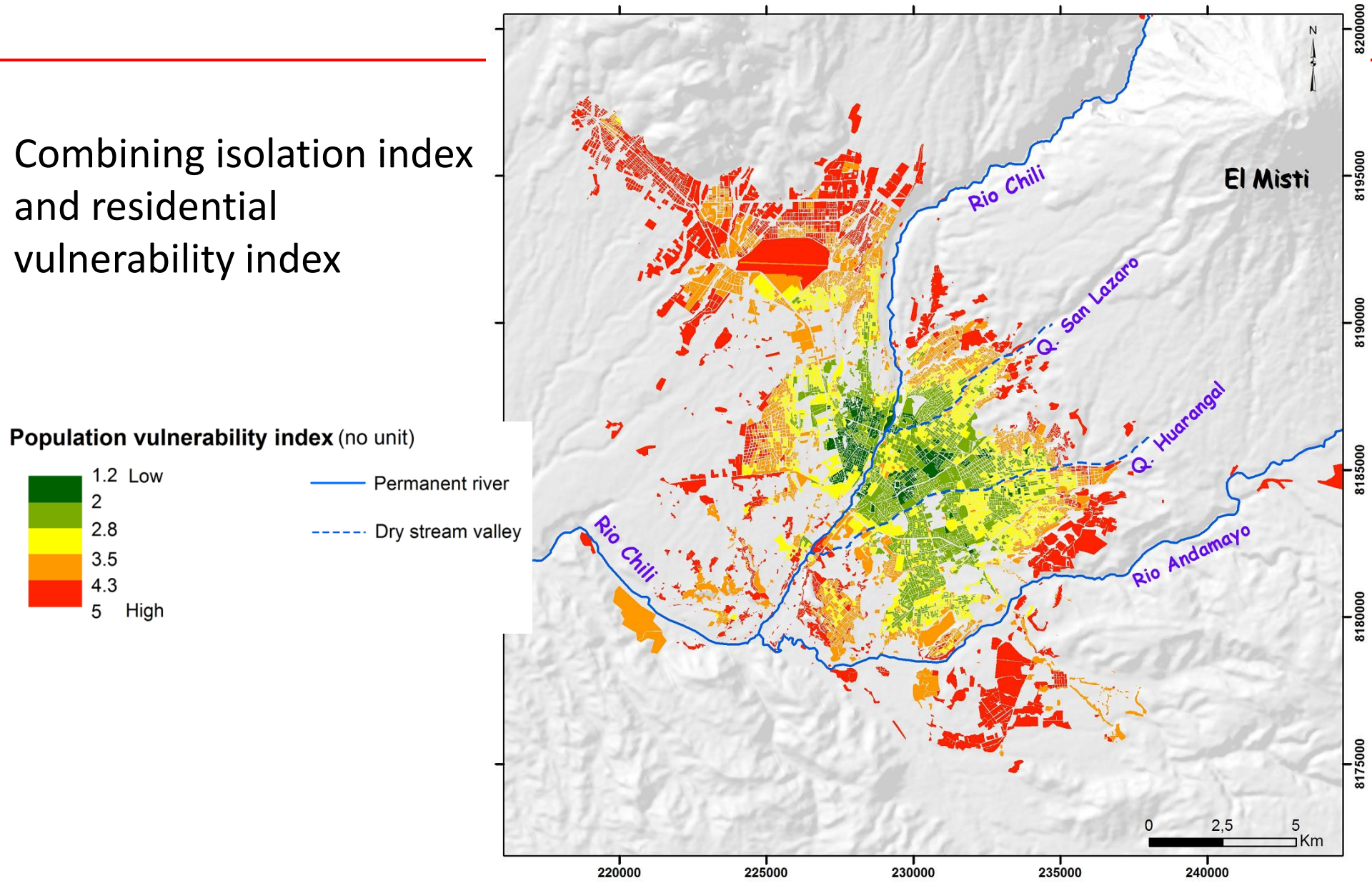
Residential vulnerability index

Name	Data used	Sour
Building size	Number of storeys	Muni Provi Areq
Building conservation	Expert knowledge	Muni de A
vulnerability index (BuV)		
Residential vulnerability index (RvI)		



Population vulnerability index

Combining isolation index and residential vulnerability index

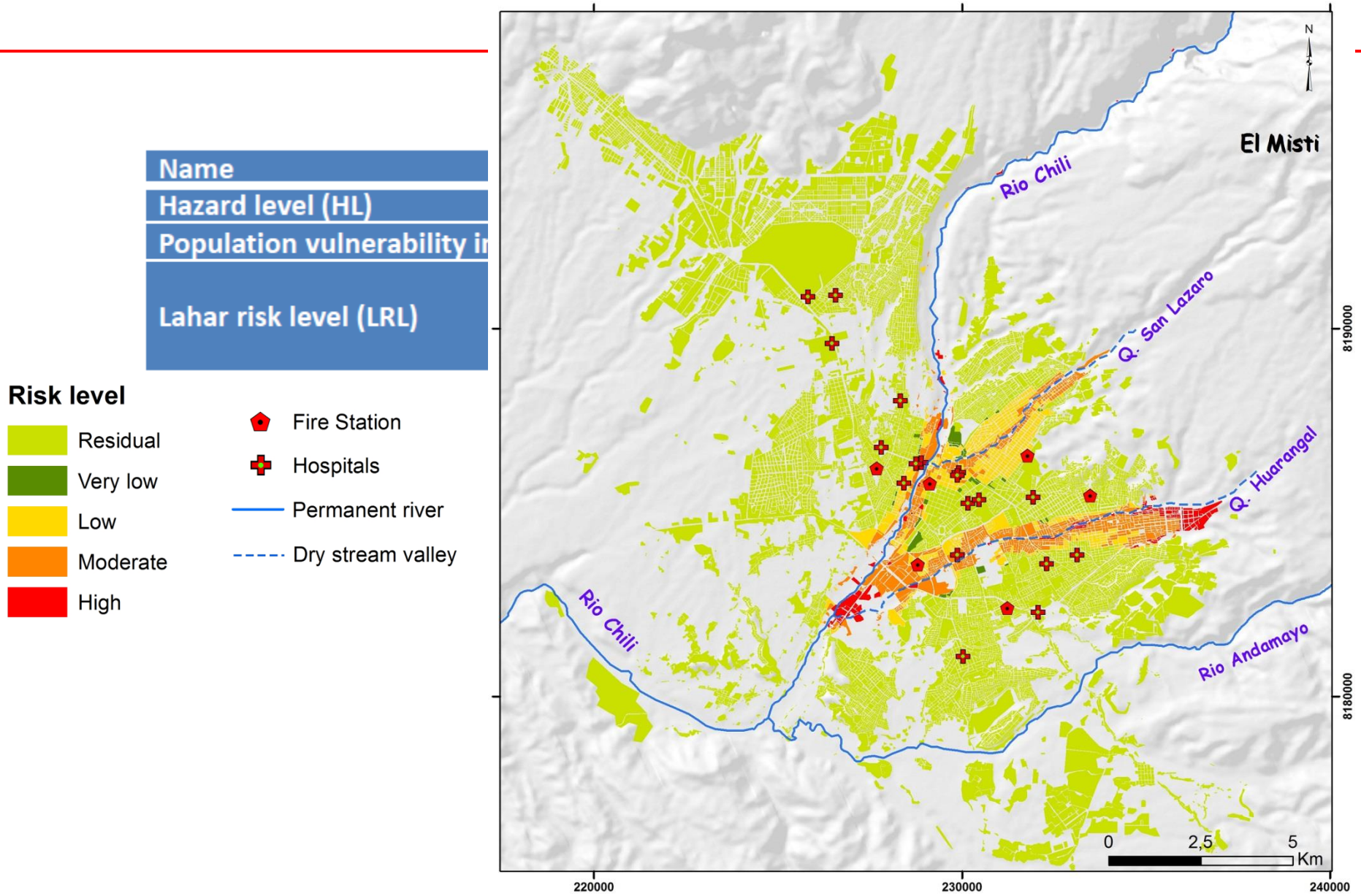


Population risk level

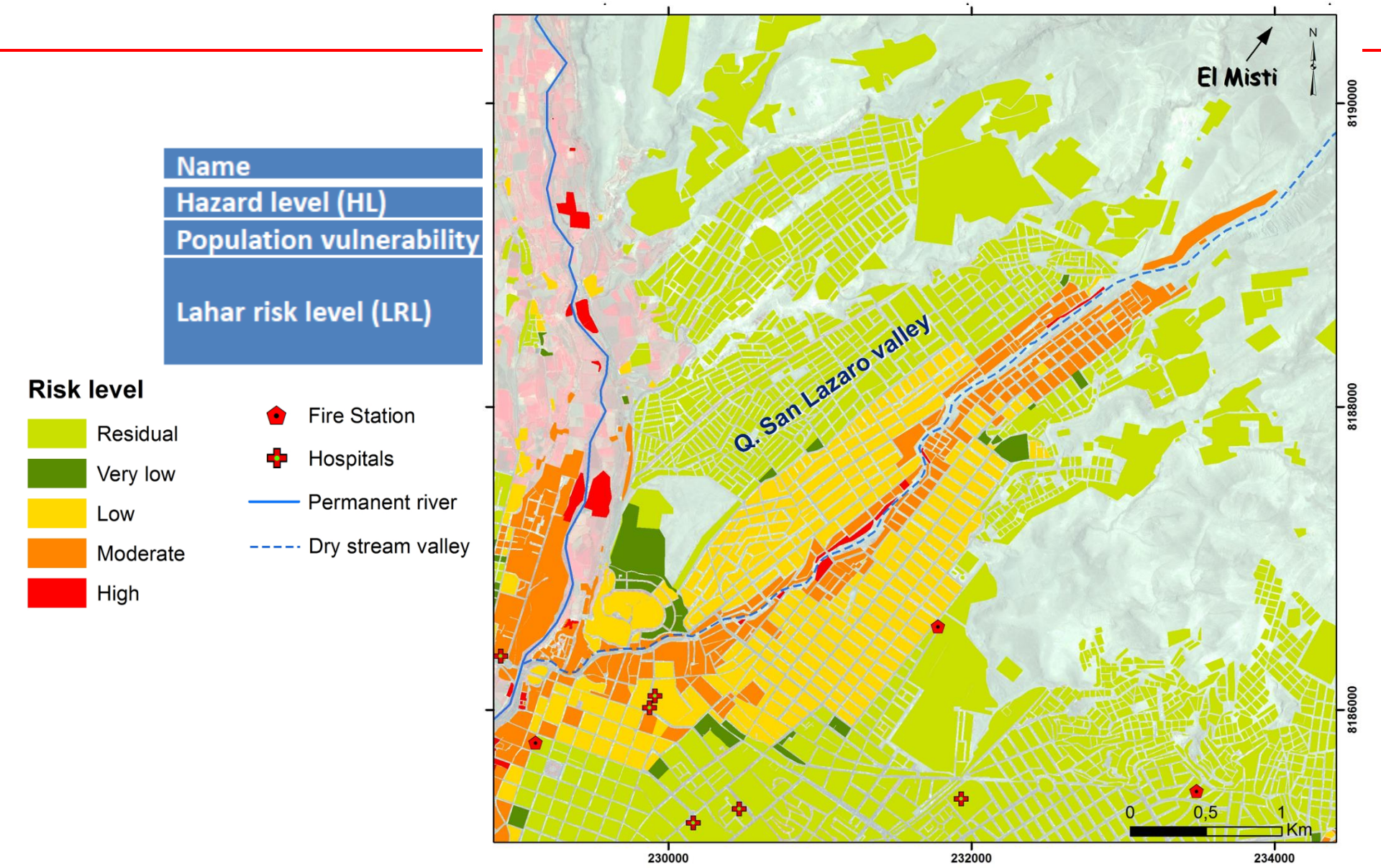
Name	Calculation
Hazard level (HL)	From 1 to 5 (Table 3)
Population vulnerability index (PvI)	From 1 to 5 (Table 7)
Lahar risk level (LRL)	If PvI=0, LRL=0 If PvI>0 and HL≤1, LRL=1 If PvI>0 and HL>1, LRL=(PvI+HL)/2

Population risk intensity

Name
Hazard level (HL)
Population vulnerability ir
Lahar risk level (LRL)



Population risk level



Physical vulnerability

Vulnerability of city blocks based on 9 criterias

Methods	Criteria	Parameters	Type
Based on photo-interpretation	Type of city block	Elevation of building and number of storeys	building indice
		Building material	
		Status or maintenance	
		Type of roof	
	Heterogeneity	building size and land use	building indice
	Housing density of the city block	density and adjacent housing	building indice
	Compact shape of the city block	shape and regularity	building indice
	Density of street network	inside and surrounding city block	building indice
	Type of alluvial terraces	elevation above river channel	geographical indice
	Angle of impact	situation and angle	geographical indice
Based on the SPOT-RSE DEM	Average slope of the city block	slope and location on terrace systm	geographical indice
Based on a geologic map	Bedrock and geotechnical soils		geographical indice

Physical vulnerability

Five « building » criterias

Methods	Criteria	Parameters	Type
Based on photo-interpretation	Type of city block	Elevation of building and number of storeys	building indice
		Building material	
		Status or maintenance	
		Type of roof	
	Heterogeneity	building size and land use	building indice
	Housing density of the city block	density and adjacent housing	building indice
	Compact shape of the city block	shape and regularity	building indice
	Density of street network	inside and surrounding city block	building indice
	Type of alluvial terraces	elevation above river channel	geographical indice
	Angle of impact	situation and angle	geographical indice
Based on the SPOT-RSE DEM	Average slope of the city block	slope and location on terrace systm	geographical indice
Based on a geologic map	Bedrock and geotechnical soils		geographical indice

Physical vulnerability

Four « physical » criterias

Methods	Criteria	Parameters	Type
Based on photo-interpretation	Type of city block	Elevation of building and number of storeys	building indice
		Building material	
		Status or maintenance	
		Type of roof	
	Heterogeneity	building size and land use	building indice
	Housing density of the city block	density and adjacent housing	building indice
	Compact shape of the city block	shape and regularity	building indice
	Density of street network	inside and surrounding city block	building indice
	Type of alluvial terraces	elevation above river channel	geographical indice
	Angle of impact	situation and angle	geographical indice
Based on the SPOT-RSE DEM	Average slope of the city block	slope and location on terrace systm	geographical indice
Based on a geologic map	Bedrock and geotechnical soils		geographical indice

Heterogeneity/homogeneity of city blocks

100 %: totally heterogeneous in size, shape, use and age of construction ?

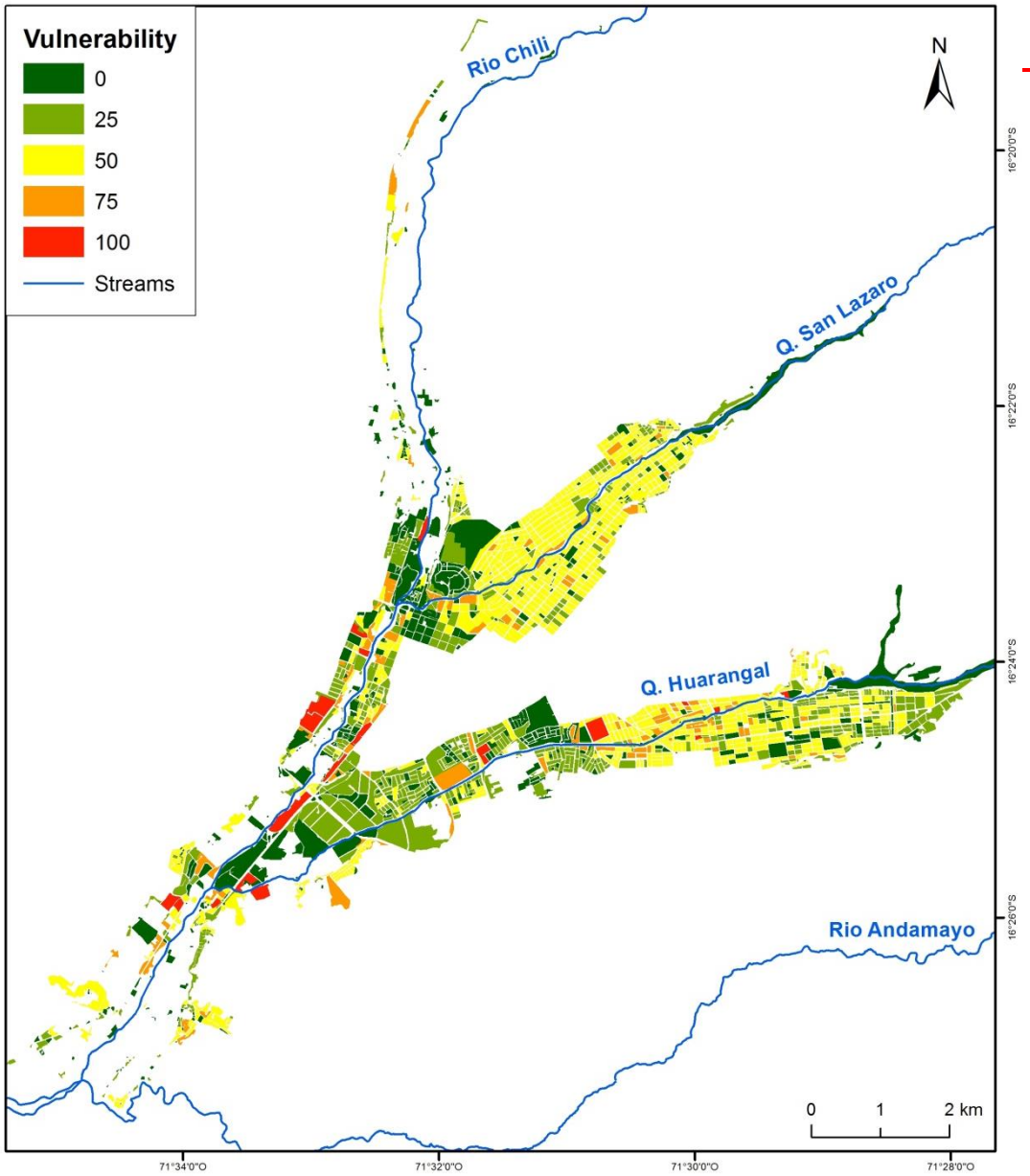
75 %: heterogeneous size and land use but similar age of construction and standard of living

50 %: relatively heterogeneous: relatively similar land use but different building size and shape

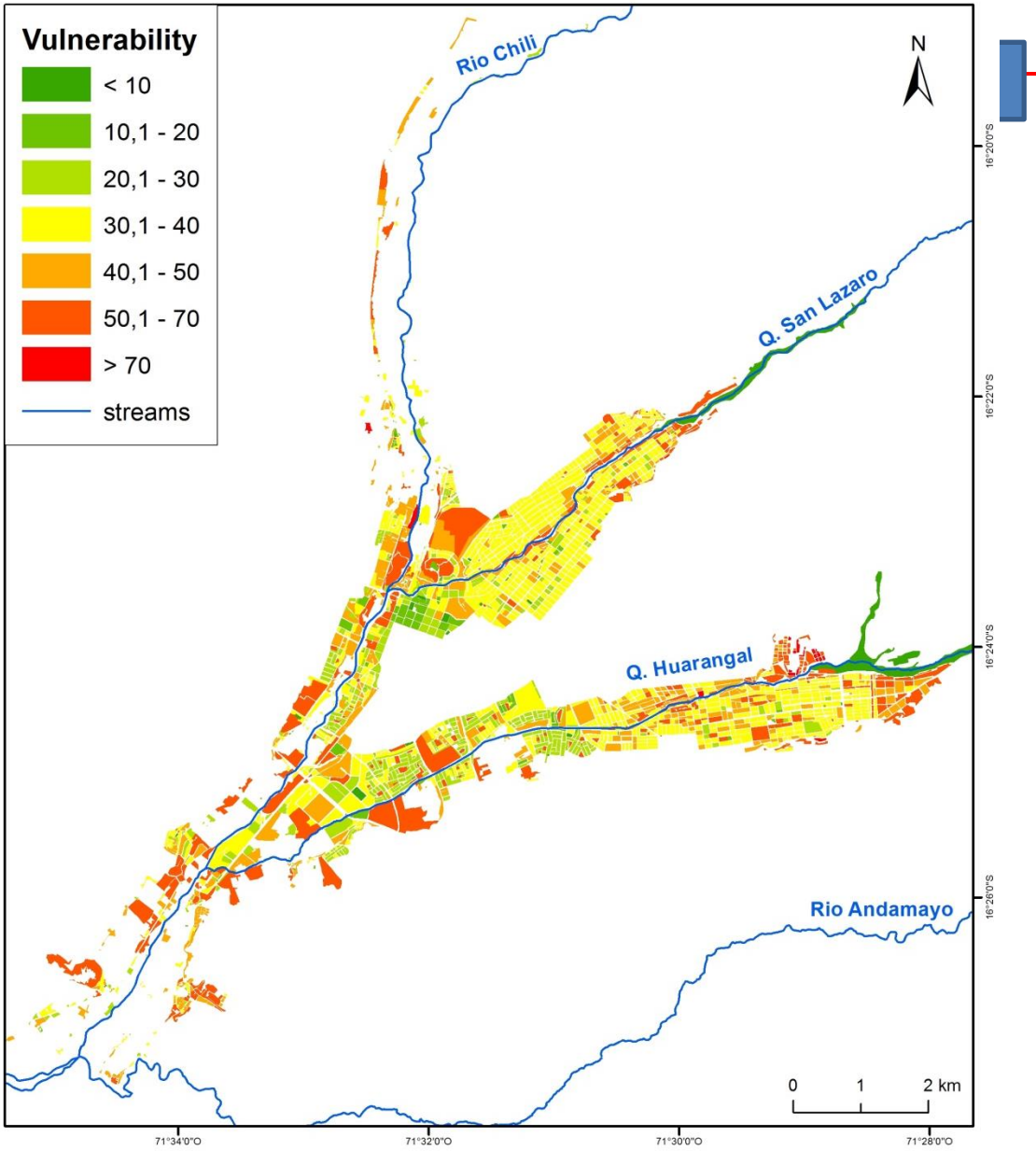
25 %: homogenous land use but heterogeneous in size and shape

0 %: homogeneous : similar building type, size and land use

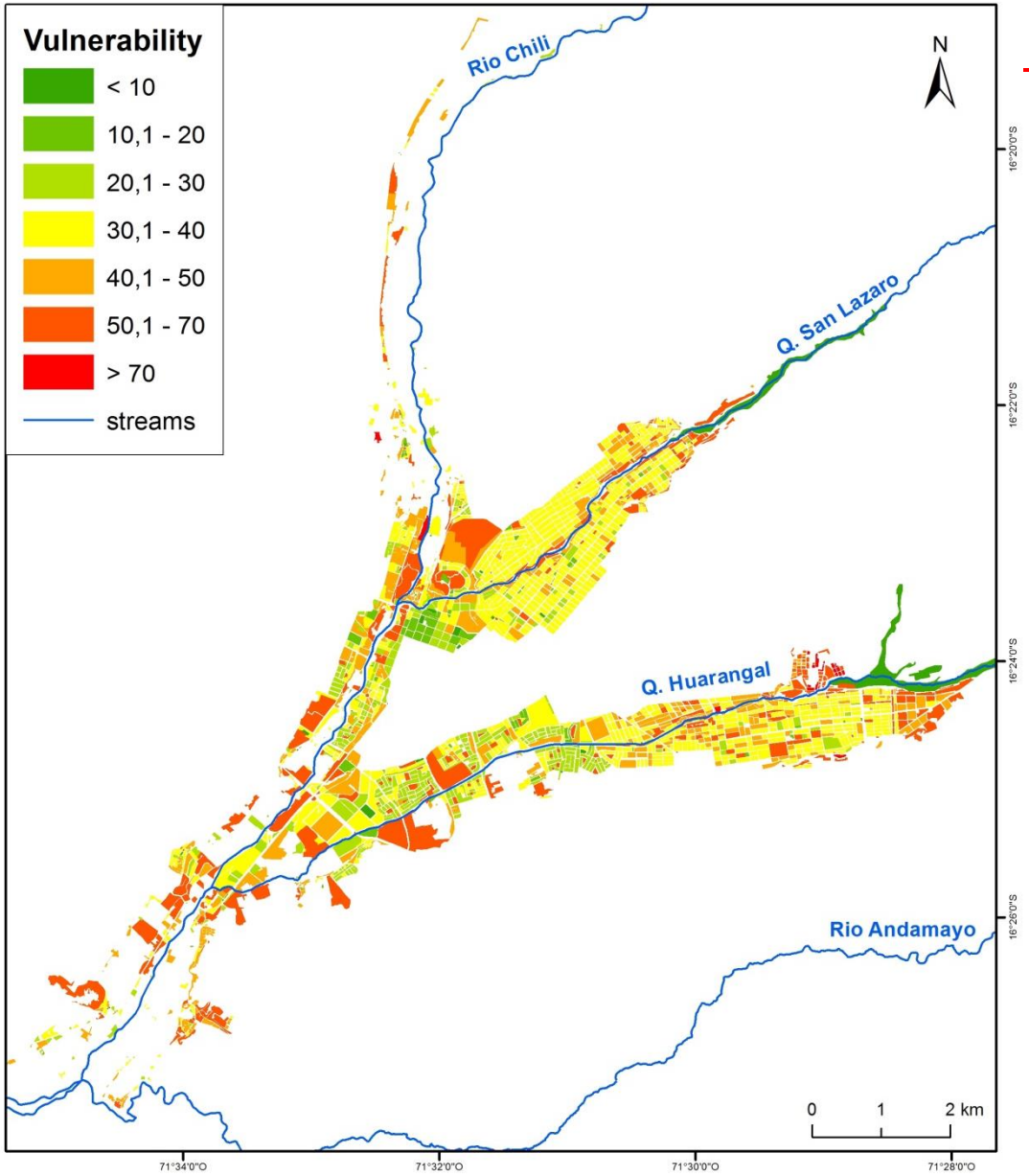
Heterogeneity/homogeneity of city blocks



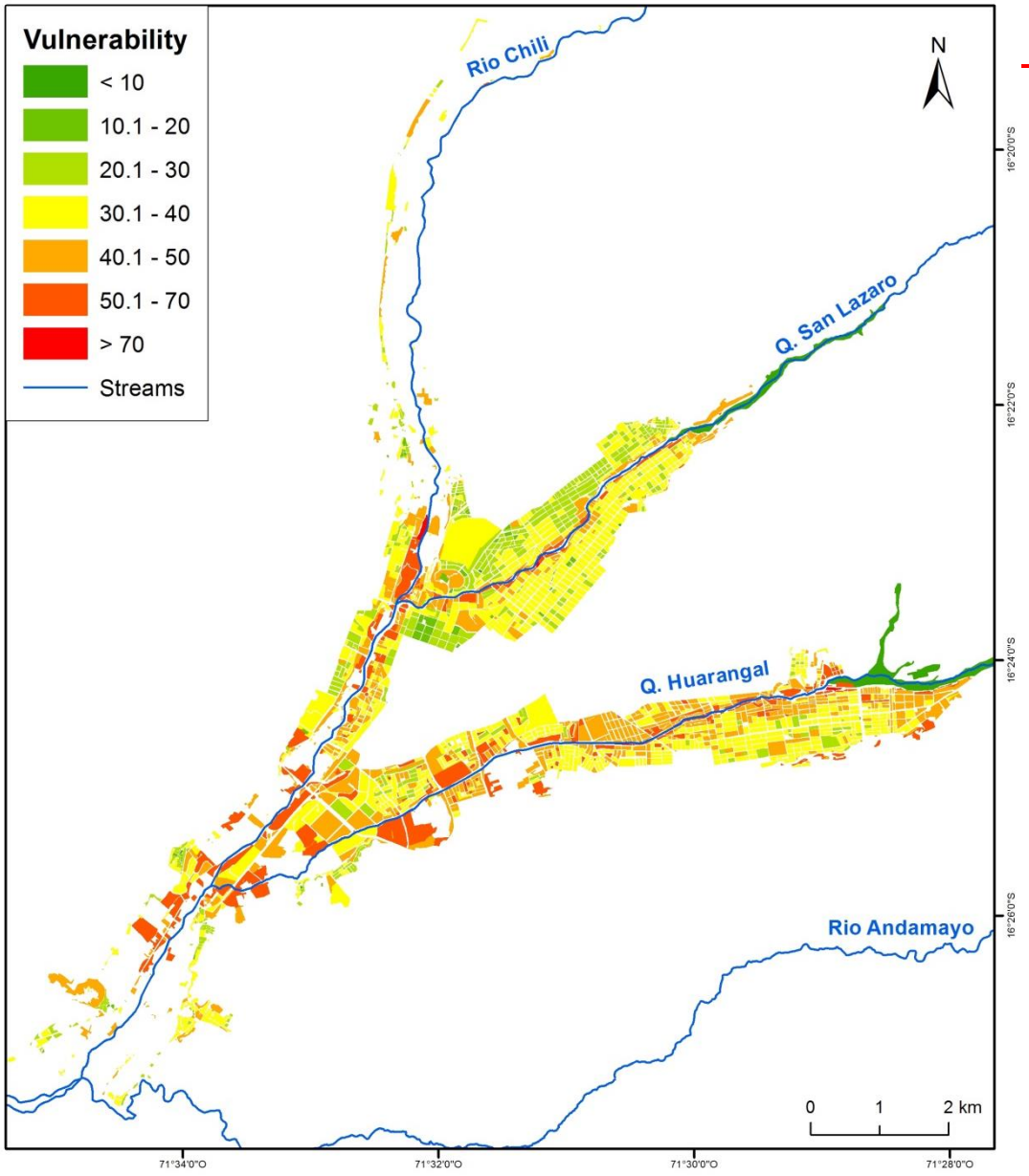
Vulnerability map based on building criterias



Exposure map based on physical criterias



Physical vulnerability map based on all criterias



Building survey

Access to satellite imagery with high spatial resolution (< 1 m)

→ Pléiades images : 50 cm

→ Free Google images (Google Earth, QGIS)

Work at building scale

Building survey

Detection of « hidden » buildings in city blocks to complete field survey

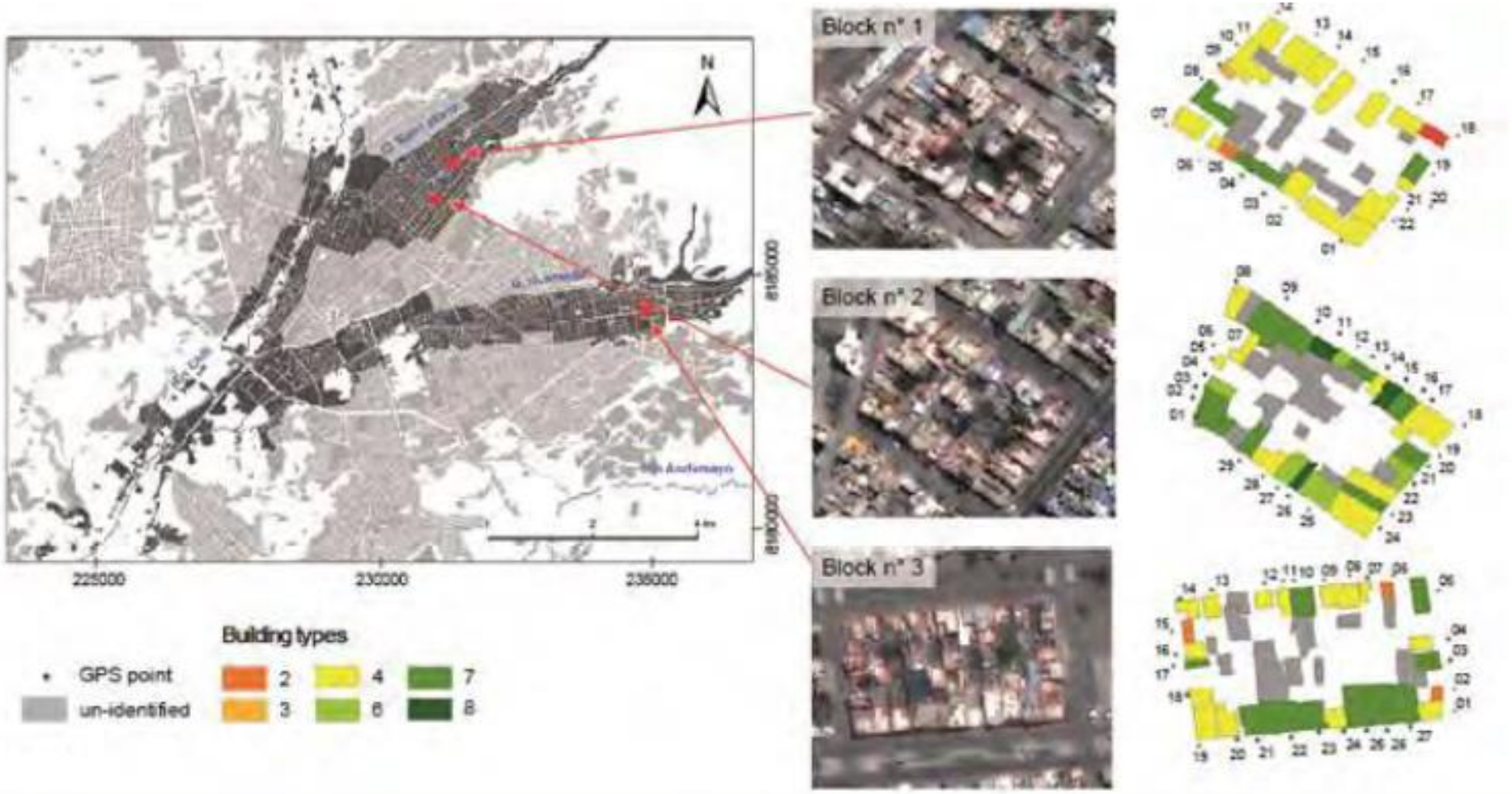


Image interpretation with field survey observations: 79%

Complete field survey

Access to roof type

Ex Qda Dahlia

Gracias por su attention