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Rapid physical and economic vulnerability assessment of the elements affected by Active Deformation Areas (ADA) detected by radar interferometry in the central Pyrenees of Catalonia (Spain)

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Local solutions to disasters: Risks, impacts and adaptation

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ICGC Institut Cartogràfic i Geològic de Catalunya

PSIG Implementació, gestió i formació SIG

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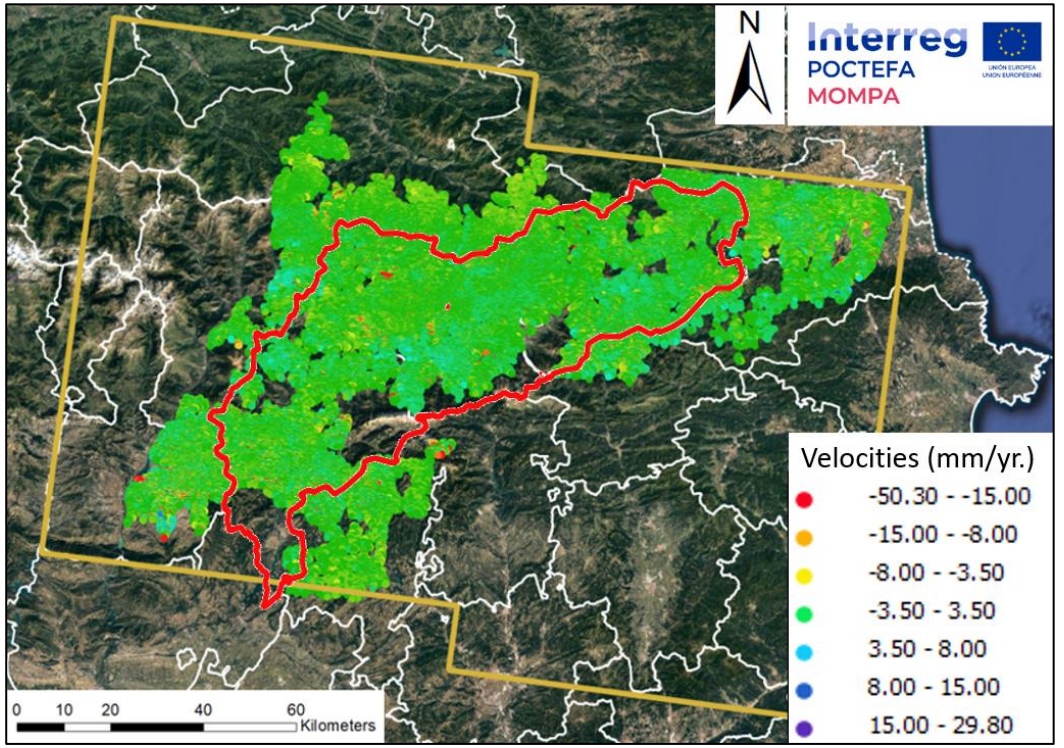
- **Methodology** for a quickly quantify of principal infrastructures (**buildings, roads,** and **railways**) structural **vulnerability in urban settlements** affected by **ground movements detected** by the Active Deformation Areas (ADA) obtained by radar satellites **interferometry** (Sentinel-1A / B and Cosmo-SkyMed).

- In the Pyrenean counties of **La Cerdanya** and **Alt Urgell** (Catalunya, NE Spain) in the **framework** of the **MOMPA project**.

- **Preliminary estimation** a long-term of **physical** and **economic vulnerability**.

- **Open information** from **Cadastral** and **topographic data** (such us, OpenStreetMap®) to calculate vulnerability.

OpenStreetMap



Mompa framework. Velocity points detected with Sentinel.

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Physical Vulnerability in buildings

- **V in buildings:** from the expected **damages** (superficial, functional or structural proposed by Cardinali *et al.*, 2002) according to the **type of building**, based on the **age of the construction.**

TYPE OF BUILDING	PERIOD (YEAR)	BUILDING STRUCTURE	RESISTANCE (from Heinimann, 1999)
A	≤1950	Light structures (simple shoring) and mixed (concrete and shoring)	Low to medium
B	1951 – 1970	Concrete and brick walls	Medium
C	>1970	Concrete and brick walls / Reinforced concrete	Medium to high

DAMAGE CLASS	VULNERABILITY RANGE
(S)- Superficial	0,01 – 0,19
(F)- Functional	0,2 – 0,29
(E) - Structural	0,3 – 1

- Physical vulnerability ranges for buildings are established according to the class of expected damage to ground movements based on the bibliographical (e.g., Solari *et al.*, 2020), and our experience.
- **Risk matrix.** Two variables: (1) construction period and (2) ADA intensity.

To determine the hazard (H), has been assumed the phenomenon intensity resulting by the ADA intensity (velocity points).

R = H * V * E

		TYPE OF BUILDING		
		A	B	C
ADA INTENSITY	I_1 (< 16 mm / year)	0,1 (S)	0,05 (S)	0,01 (S)
	I_2 (16 – 32 mm / year)	0,2 (F)	0,1 (S)	0,05 (S)
	I_3 (> 32 mm / year)	0,4 (E)	0,2 (F)	0,1 (S)

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Physical Vulnerability in roads

- **V in roads:** from the expected **damages** (superficial, functional or structural) according to the **categories (typology) of existing roads classified according to their characteristics** (motorway, local road, path…).

TYPOLOGY OF ROAD	ATTRIBUTE *FCLASS* OPENSTREETMAP*
Autopistas y Autovías	-Motorway
Carretera nacional o autonómica básica de primer nivel	-Trunk
Carretera autonómica o básica de segundo nivel	-Primary
Carretera autonómica de tercer nivel o comarcal	-Secondary
Carretera provincial o local + vías de servicio + camino residencial	-Tertiary …
Camino	-Track …
Vereda	-Footway …

DAMAGE CLASS	VULNERABILITY RANGE
(S)- Superficial	0,05 – 0,29
(F)- Functional	0,3 – 0,59
(E) - Structural	0,6 – 1

- Physical **vulnerability ranges** for roads are established according to the class of expected damage to ground movements based on the bibliographical (e.g., **Leone *et al.*, 1996 -modifiable for different areas and conditions-**), and our experience.

- **Risk matrix.** Two variables: (1) road type and (2) ADA intensity.

R = H * V * E

		TYPOLOGY OF ROADS						
		A - CM	B - CT	C - CP	D - CS	E -CT/R	F - CU/T	G – CF/S
INTENSITY ADA	I_1	0,05 (S)	0,15 (S)	0,25 (S)	0,2 (S)	0,2 (S)	0,2 (S)	0,25 (S)
	I_2	0,2 (S)	0,25 (S)	0,3 (F)	0,4 (F)	0,5 (F)	0,55 (F)	0,6 (E)
	I_3	0,4 (F)	0,5 (F)	0,6 (E)	0,7 (E)	0,8 (E)	0,9 (E)	1 (E)

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Economic Vulnerability in buildings

- **EV in buildings:** at the municipal level from the **cadastral value** (approach proposed by Pellicani *et al.,* 2014 for large areas with low availability of data).
- In Mompa: two essential **variables** for calculating EV:
  1. **m² built** (cadastral)
  2. **value second-hand market** at the comarcal level

COUNTY	Value second-hand market in 2020 (€ / m² built)
Alt Urgell	996,69
La Cerdanya	2872,11

- Consequently, the **EV is calculated as the percentage of loss in market value of each building in relation to the phenomenon intensity.** This value considers the **degree of robustness** (building type borne in mind the resistance).

- The conversion of the physical vulnerability ranges established for buildings as a percentage of value loss, the following table is presented:

DAMAGE CLASS	% OF MARKET VALUE LOSS
(S)- Superficial	5 %
(F)- Functional	25 %
(E) - Structural	50 %

		TYPE OF BUILDING		
		A	B	C
ADA INTENSITY	I_1 (< 16 mm / year)	5 % (S)	5 % (S)	5 % (S)
	I_2 (16 – 32 mm / year)	25 % (F)	5 % (S)	5 % (S)
	I_3 (> 32 mm / year)	50 % (E)	25 % (F)	5 % (S)

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Economic Vulnerability in roads

- **EV in roads**: public roads don't represent private property, so only **construction costs** (and not market values) per **m² or km²** of the different **type of roads** can be estimated (Sterlacchini *et al.*, 2014). In 2013, the **European Court of Auditors determined** that the **road cost for every 1000 linear m** is the **best measure to compare** the **cost between countries**, since it eliminates orography variables.

TYPOLOGY OF ROAD	AVERAGE COST CONST. (€ / km)
Autopistas y Autovías	7,91 millones euros / km
Crta nacional o autonómica básica de primer nivel	4,06 millones de euros / km
Carretera autonómica o básica de segundo nivel	1,2 millones de euros / km
Crta autonómica de tercer nivel o comarcal	800.000 euros / km
Crta provincial o local + vías servicio + camino res.	500.000 euros / km
Camino	60.000 euros / km
Vereda	50.000 euros / km

- **Variables**: (1) **linear km affected** by **ADA**, (2) **construction cost** by typology.
- The conversion of the physical vulnerability ranges established for roads as a % **of value loss**, the following table is presented. This % of value loss has been determined based on references (e.g., Catani *et al.*, 2005) and expert criteria. The value **considers** the **degree of robustness**: the typology assigned according to the resistance of the road infrastructure to ground movements.

DAMAGE CLASS	% OF VALUE LOSS
(S)- Superficial	20 %
(F)- Functional	40 %
(E) - Structural	80 %

		TYPOLOGY OF ROAD						
		A - CM	B - CT	C - CP	D - CS	E -CT/R	F - CU/T	G – CF/S
ADA INTENSITY	I_1	20 % (E)	20 % (E)	20 % (E)	20 % (E)	20 % (E)	20 % (E)	20 % (E)
	I_2	20 % (S)	20 % (S)	40 % (F)	40 % (F)	40 % (F)	40 % (F)	80 % (E)
	I_3	40 % (F)	40 % (F)	80 % (E)	80 % (E)	80 % (E)	80 % (E)	80 % (E)

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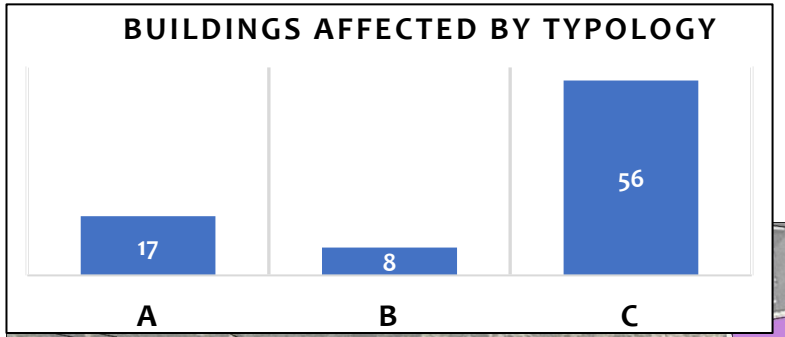
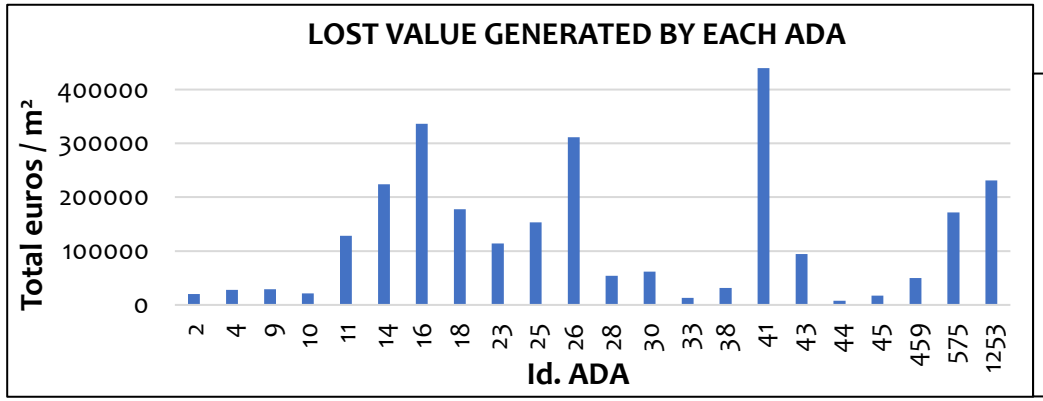
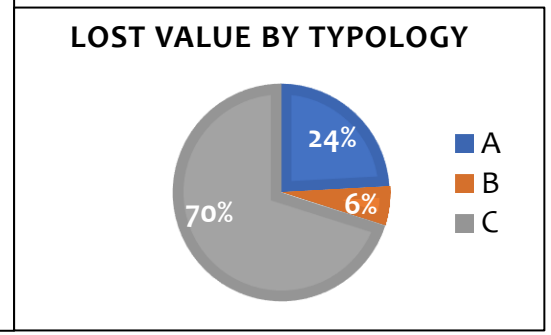
Example of results in buildings

- Calculating **vulnerabilities** on **regional scales** and with large volumes of data can be complicated (**2,000 km²; 400 ADA**) ➡ a **PostgreSQL database** with the PostGIS module **has been designed to perform calculations and analyzes quickly and semi-automated.**
- **81 buildings** have been **affected by ADA and affectations** in the 3 type of buildings.
- The **loss value** has been **calculated based on the second-hand market** for the **year 2020**, yielding total losses of **2,716,656.62** € among the **81 affected buildings**.
- **By typology**, the losses are distributed as follows**: 656,000.05 €** (24% of the total) for **type A; 155,732.81 €** (6%) for type **B** and **1,904,923.76 €** (70%) for type **C**.







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Thanks for your attention

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